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U. S. DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
ANIMAL HUSBANDRY RESEARCH DIVISION
and
COOPERATING WESTERN STATES

W-1 - IMPROVEMENT OF BEEF CATTLE THROUGH THE APPLICATION OF
BREEDING METHODS

1963 Annual Report of W-1

and

Report of
Annual Meeting of Technical Committee
Logan, Utah
August 19-20, 1963

This report is intended for the use of
administrative leaders and workers and
is NOT for general publication.



Annual Report of W-1
and
Report of
Annual Meeting of Technical Committee

Utah State University

Logan, Utah

August 19 and 20, 1963

PROGRAM

Dr. George E. Nelms, Chairman

August 19

- 8:00 A.M. Welcome to Utah State University
Dr. D. W. Thorne, Director, Utah Agricultural
Experiment Station, expressing his views on
regional research
- 8:25 A.M. Theme of 1963 Annual W-1 Technical Committee Meeting
Dr. George E. Nelms
- 8:40 A.M. Methods of Selection for Maximum Utility Value
Dr. Robert W. Allard, Professor of Agronomy,
University of California, Davis
- 10:15 A.M. Application of Recombinations in Research
Dr. L. J. Sumption, Department of Animal Husbandry,
University of Nebraska, Lincoln
- 11:00 A.M. Possible Uses of Recombination in the Animal Field
as a Prelude to Sound Crossing Systems
Dr. Weslie Combs, Department of Animal Science,
University of Alberta, Edmonton, Alberta
- 12:00 Lunch
- 1:00 P.M. Discussion
Dr. L. J. Sumption, Moderator
- 3:00 P.M. Comments
Dr. S. S. Wheeler, Administrative Adviser
- 3:30 P.M. Station Reports
- 6.30 P.M. Dinner
Dr. G. W. Cochran, Department of Botany and
Plant Pathology, Utah State University,
Speaker

August 20

- 8:00 A.M. Station Reports
Tour of Utah Experiment Station facilities
- 12:00 Lunch
- 1:00 P.M. Revisions and New Projects
Business Meeting
Comments of Branch Chief, CSESS Representative, and
and Visitors

ADJOURN

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ANNUAL MEETING
W-1 Technical Committee
Utah State University
Logan, Utah
August 19 - 20, 1963

George E. Nelms, Chairman

Project Leaders Present

Arizona	O. F. Pahnish
California	W. C. Rollins
Colorado	V. B. Swanson*
Hawaii	Estel H. Cobb
Idaho	R. E. Christian
Montana	F. S. Willson
Nevada	C. M. Bailey
New Mexico	L. A. Holland
Oregon	Ralph Bogart
Utah	J. A. Bennett
Washington	C. C. O'Mary
Wyoming	G. E. Nelms
U. S. Range Livestock Experiment Station	N. M. Kieffer

Regional Administrative Adviser

S. S. Wheeler

Agricultural Research Service

Investigations Leader
Research Geneticist

R. T. Clark
J. S. Brinks

Chief, Beef Cattle Research Branch

E. J. Warwick

Cooperative State Experiment Station Service

Principal Animal Husbandman

M. J. Burris

*Representing H. H. Stonaker

The Chairman, Dr. George E. Nelms, called the meeting to order at 8:00 A.M. August 19. He introduced Dr. D. W. Thorne, Director of the Utah Agricultural Experiment Station.

Dr. Thorne:

These are times when we are shifting our thinking about regional research. I have considerable reservation about the change, but I think this is no reason why we should not try something even though it is somewhat of a change in philosophy from what we have had in the past.

One problem has been a complaint on the part of the committees that they did not want to be involved in financial matters. Most technical committees have different subcommittees that review projects and bring in recommendations. There are some complaints of favoritism. I am sure you will not get away from criticism, no matter what kind of system you use.

Dr. Farrell of Pennsylvania made a survey and in the West there were some criticisms on the division of funds.

Another thing--year after year the number of regional projects has increased, and in spite of the shift in philosophy we agree that we should decrease the number of projects. We agree none are financed adequately and we should have fewer, but we agree on most projects. So now it is hoped that the directors individually may be able to reduce the number of projects where collectively the directors have failed. It may decrease to some extent the number of projects each state is participating in. It may increase the total number of regional projects.

Another problem--regional research was conceived with the idea that we might set up a few centers. Beef cattle was one. If we had a few centers it might eliminate a number of research projects in individual states. But the evidence is to the contrary, to the thinking of the people in the work. If we put the money where the states have the greatest facilities, then it accentuates the problem of the rich getting richer, the poor getting poorer. Usually the richer states have the best facilities and get the greater amount of money, so that hasn't worked out. I am skeptical about this new mode having any merit although some thought is being given to this matter of research centers, for if the regional money comes through this year or next for research eventually the question must be answered, "Do we want a regional facility of some kind and do we use regional research funds for such a facility?"

Last year there was no major request for a regional facility and we don't know of any request from any regional research group for a regional facility. I don't know whether an additional \$1 million that might be appropriated for research might be used for a regional research facility or whether it would be divided among the states. This is a problem for the committees to discuss. Would a central facility serve the purpose of research more effectively than state research?

We have introduced two changes. One, a change in the regional research outline. There has been some feeling this might help in regional planning. At least a third of the projects, maybe more, have been very poorly planned. These projects have gone along from year to year and there has been a series of stress and strain between the committee and the directors.

The new project outline does away so far as Cooperative State Experiment Station Service is concerned with state outlines. You have only one outline which serves all states and each state will have to indicate very briefly in the outline just what it will do. These will be down to one or two pages where the committee can look at it and say, "Is this a coordinated attack?" It will throw a little more control into the hands of the Committee of Three who control our regional research projects. The Committee will take the stand that it will approve or reject the whole project. Some are being turned

down. This seems drastic, but it is the only way the Committee can operate. This is a period when we are going to have considerable stress to orient these programs. I believe, however, it is almost necessary nationally and every other way. Research is being scrutinized very carefully, and while research stations have not shared the bounties that have fallen from NIH, NASA, and others, they still must bear up under the same scrutiny.

I feel myself regional research has been highly successful. So far as the men in my own station have been concerned, they have been greatly helped by going to these committee meetings. And those who have been helped the most are those who have gone to the committees that are most alert and most critical. We feel grateful that in many cases the committees have provided a stimulating and critical attitude toward research. Good committees have been doing more than putting a premium on good fellowship and fear that criticism is going to mar the harmony. I believe regional research committees must take up questions critically and must assume quite a critical attitude toward the research done so that, as states come in with projects, the projects and contributions must be evaluated and if they are not carrying their own share they must not be included in the project.

We welcome you here to the campus of Utah State University. We had hoped to have our new livestock facility further along so we could display it to better advantage. All we have is a piece of ground still quite raw, some plans, and some money in the bank. We hope next time you are here we will have a better set-up for displaying our regional research and local research in the livestock program in nutrition, management, and disease. Our program has been expanding fairly rapidly and we have been having considerable growth pains. In the past few years the campus has taken over three of our farms and this has left a number of scars, for Animal Husbandry is the department that has been moved.

I have not discussed any of our specific programs at Utah State University, but some of the staff members will take you out and show you what we have and if there are any questions, we will be glad to try to answer them.

Thank you for coming. We hope you will come again.

Dr. Nelms:

The theme of our W-1 meeting this year is Genetic Recombinations. With a breeding program in cattle such as we have, it is difficult to present anything new each year. We felt that perhaps every other year, or every third year, each station might be able to give a report, and at each meeting the remainder of our time would be devoted to getting new thoughts before the group on new things, new ideas to work with. Genetic recombinations or whatever other name might be given is one that is not talked about a lot in animal breeding circles, maybe not in plant circles.

We will go on with the part of the meeting I am looking forward to--the next three speakers. Dr. Sumption and Dr. Combs feel they may have covered a lot of the same material, but I am sure we will feel they have offered us much to think about. The first man on the program is Dr. Allard.

SOME POPULATION PARAMETERS AND THE UTILIZATION OF EXOTIC VARIABILITY IN PREDOMINANTLY SELF-FERTILIZED CROP PLANTS

R. W. Allard

University of California, Davis, California

I. Introduction

One of the postulates of population genetics is that adaptation (fitness to a given environment) and adaptability (capacity for genetic change in adaptation) are antagonistic. According to this postulate highest adaptation occurs when a population consists of the few genotypes which have highest fitness to the particular environments which the population encounters. Conversely, high adaptability depends on genetic variability which is the very antithesis of close adaptation. It follows that successful breeding, insofar as it achieves ever higher adaptation, tends to reduce genetic variability and thus also to reduce long-term capacity for change. There is in fact substantial evidence that rapid technological gains in advanced plant agricultures in the last century or so have increased adaptation at the expense of adaptability and that we are now dealing with essentially plateaued populations in many of our plant breeding programs. I believe this is one of the most important, if not the most important of the broader problems of present day plant breeding, and my remarks today will be directed toward a possible solution.

Since the solution to this problem is related to the causes it will be worthwhile to reflect briefly on the reasons our populations are presently not advancing at the rate we would like. The difficulty is, I believe, compounded of three chief factors: accidents of sampling, intense selection, and small population size. Most of our present day crop varieties adapted to some particular geographical region are based on the sample of variability which was available in the early days of cultivation in that region. This original sample of variability is known in many well documented cases to have been a limited and haphazard sample. Similarly, subsequent introductions which may occasionally have widened and enriched the genetic base of the locally adapted types must also have been haphazard samples because plant introduction as a deliberate and well organized activity is a recent innovation. On the grounds of sampling alone, it therefore seems inconceivable that anything like all of the potentially useful genes and gene combinations were ever available at any one place; it is much less likely that they have ever been assembled into any group of locally adapted stocks.

The solution to this problem was obviously to develop large collections of genetic variability in our crop plants, and in many crops collections consisting of thousands of entries have been available for many years. However, these collections have for the most part been regarded as sources of "characters," such as disease resistance, which are transferred to locally adapted backgrounds by rigorous selection or by a series of backcrosses. Thousands of such operations have been performed

and they have made many desirable genes available to breeders. Nevertheless, despite the publicity that such spectacular methods attract, I believe it is safe to say that most plant breeding progress has come and will continue to come from the steady unspectacular advance in performance that attends selection amongst the progeny of hybrids between locally adapted types. The stuff of which this "regular" plant breeding is made is the recombinational potential within the limits of locally adapted types. Once this recombinational potential is exhausted, further advance must be at an end unless the genetic base is broadened. By and large, the manner in which germplasm banks have been employed has precluded that they should make any substantial contribution toward broadening the genetic base and providing the continuing supply of novel locally adapted types that are necessary for sustained progress.

The reasons why germplasm banks have been used as sources of "characters," and have not contributed as much as might have been hoped towards broadening the genetic base, are clear enough. The entries in such world collections are mostly ill-adapted and every breeder knows that to use poor parents is to invite poor progeny. Simple arithmetic shows why this is the case. If an adapted and unadapted variety differ by only a few genes, and there are in addition some unfavorable linkages, the probability that transgressive segregants will occur becomes vanishingly small. Hence crosses between adapted and unadapted types nearly always fail, sometimes no doubt because the ill-adapted parent has nothing to contribute but probably more often because the intense selection and small population sizes associated with ordinary breeding programs reduce the chance of success to nil. It is obvious that unadapted types must often have real potential because otherwise our crops could not have made the transformation from wild plants to their present "advanced" state. The reason standard breeding methods are inadequate to the task of exploring the range of useful variability in a species is probably that they simply do not allow numbers and time necessary for the required recombinations to take place.

I shall now try to summarize and generalize the argument. First, the very successes of plant breeding in the past century or so have often been achieved at substantial cost to the materials of future change. Second, while breeding from locally adapted strains has led to progress, there is a limit to achievement on this basis and in some cases this limit appears to have been reached. Third, the large collections of types which have recently been assembled in germplasm banks provide modern breeders with great opportunities for progress; the problem is to isolate desirable genes and gene-combinations in usable form from these collections. Fourth, conventional breeding methods must be rejected for this purpose on the operational considerations that the combinations are too numerous, the numbers of progenies required too large, and the probability of success too small in any single hybrid to justify the effort and expense involved. Fifth, and finally, some method is needed which will permit the variability which now goes to waste to be explored and exploited.

In principle, so-called "mass reservoirs" might provide the needed technique. Mass reservoirs are readily set-up on a broad genetic base by merely mixing large numbers of strains and they allow very large populations to be handled at negligible cost by mass-propagation methods. However, such mass-propagated populations will give rise to a continuing supply of novel and useful adapted variants only if two conditions are satisfied: first, the population must not go to fixation but must remain a dynamic recombinational system over many generations; second, survival in such populations must be positively correlated with agricultural value. Whether these two conditions are satisfied will depend on the numerical values assumed by population parameters specifying such factors as mating system, adaptive values of various genotypes, interactions between loci, and other factors which affect amounts of genetic variability and the course of genetic change in populations. Consequently the plan in this talk is first to consider the factors which affect population structure and then to consider the predictions which numerical estimates of these factors permit regarding the long range future of broadly based mass-reservoirs as a source of locally adapted variability.

The basis of the discussion will be studies of a number of experimental populations of predominantly self-pollinated species, especially certain populations of lima beans, barley, and wheat, on which observations have been made over many generations on mating systems, on the course of change in gene frequencies for various major "marker" genes, and on various measurement characters, including yield (e.g., Suneson, 1956; Harlan, 1956; Jain and Allard, 1960; Allard and Jain, 1962; Allard and Workman, in press). Some of these populations were derived from hybrids between two homozygous parents, others were synthesized by compositing hybrids representing many different parents, and still others by the mere mechanical mixing of two or more homozygous parents. Each of the populations was maintained without conscious selection and a census taken regularly to determine the frequency of the two homozygotes and the heterozygote at each of a number of "marker" loci. Estimates of the amount of selfing versus outcrossing were made periodically by drawing a random sample of individuals of recessive phenotype from the population, growing their progeny, and scoring the proportion of individuals with dominant and recessive phenotypes. Then, since allelic frequencies in the pool of pollen grains can be estimated from the census data, it is possible to compute the frequency of outcrossing (Allard and Workman, 1962). In the barley and lima bean populations to be discussed the mean amounts of outcrossing were found to be about 1 percent and 5 percent, respectively, which are near the values commonly observed in these two species.

II. Studies of "Marker" Loci

A. Single Locus Cases

In studies of population structure one of the most common procedures has been to concentrate on single genetic entities. The work of

Dobzhansky and his coworkers on inversion sequences in Drosophila pseudotscura are examples of studies based on blocks of genes which act as single loci in heredity, and the work of Kerr and Wright (1954) exemplify studies of "single" loci. It should be emphasized that when single major genes are followed in a population the hereditary unit is not the major marker locus alone, but the marker locus and all more or less closely linked loci. Thus the hereditary unit is a segment of chromosome which undoubtedly varies in composition from generation-to-generation. In the present populations the mean length of segment, as constituted in the homozygous parents, is expected to decrease gradually with advance in generation, but as will be shown later, the segments in consideration are likely to be longer than 20 crossover units after 40 generations in the populations studied.

Some representative patterns of change in the frequencies of the two homozygotes and the heterozygote for marked chromosome segments in three lima bean populations are illustrated in figure 1. In each case the frequencies changed rapidly in the first 3 or 4 generations. Thereafter the population point fluctuated in aimless fashion about apparent equilibrium points. The pattern of change for $\underline{D}/\underline{d}$ and $\underline{S}/\underline{s}$ in populations 20 and 75 suggest that the $\underline{D}$ and $\underline{S}$ segments are adaptively superior to the alternative segments marked by $\underline{d}$ and $\underline{s}$, whereas the behavior of $\underline{S}/\underline{s}$ in population 65 suggests near equality in fitness of the two homozygotes. It will be noted that a substantial and fairly constant proportion of heterozygotes occurred in the later generations for these three marked segments, and also for several other segments for which the population point of only the last available generation is plotted. Similar results have been observed in experimental barley populations into generation 20 or later and also in natural populations of wild oats (5 percent outcrossed). These observations suggest that levels of heterozygosity in predominantly self-pollinated species are higher than has commonly been supposed and they raise the question of the factors which allow this heterozygosity to be maintained in conflict with the high levels of inbreeding. In particular it would be interesting to know whether present genetic composition is what one would expect from estimates of the fitnesses of the various genotypes and what the likely future of these populations may be.

The concepts to be used are found in the papers of Wright (1942, 1949), Hayman (1953), Li (1955), Lewontin (1958), and Lewontin and White (1960). Let q and $(1-q)$ be the frequencies of the "alleles" a_1 and a_2 , s and t the amount of selfing and outcrossing ($s + t = 1$) and let w_1 , w_2 and w_3 and f_1 , f_2 and f_3 be the relative selective values and relative frequencies of the genotypes a_1a_1 , a_1a_2 and a_2a_2 , respectively. It can then be shown that the population will rapidly come to equilibrium for an inbreeding coefficient $F = \frac{1-t}{1+t}$ and that the equilibrium genotypic frequencies will be $(1-F)q^2 + Fq:2(1-F)q(1-q):(1-F)(1-q)^2 + F(1-q)$. If the w_i are independent of

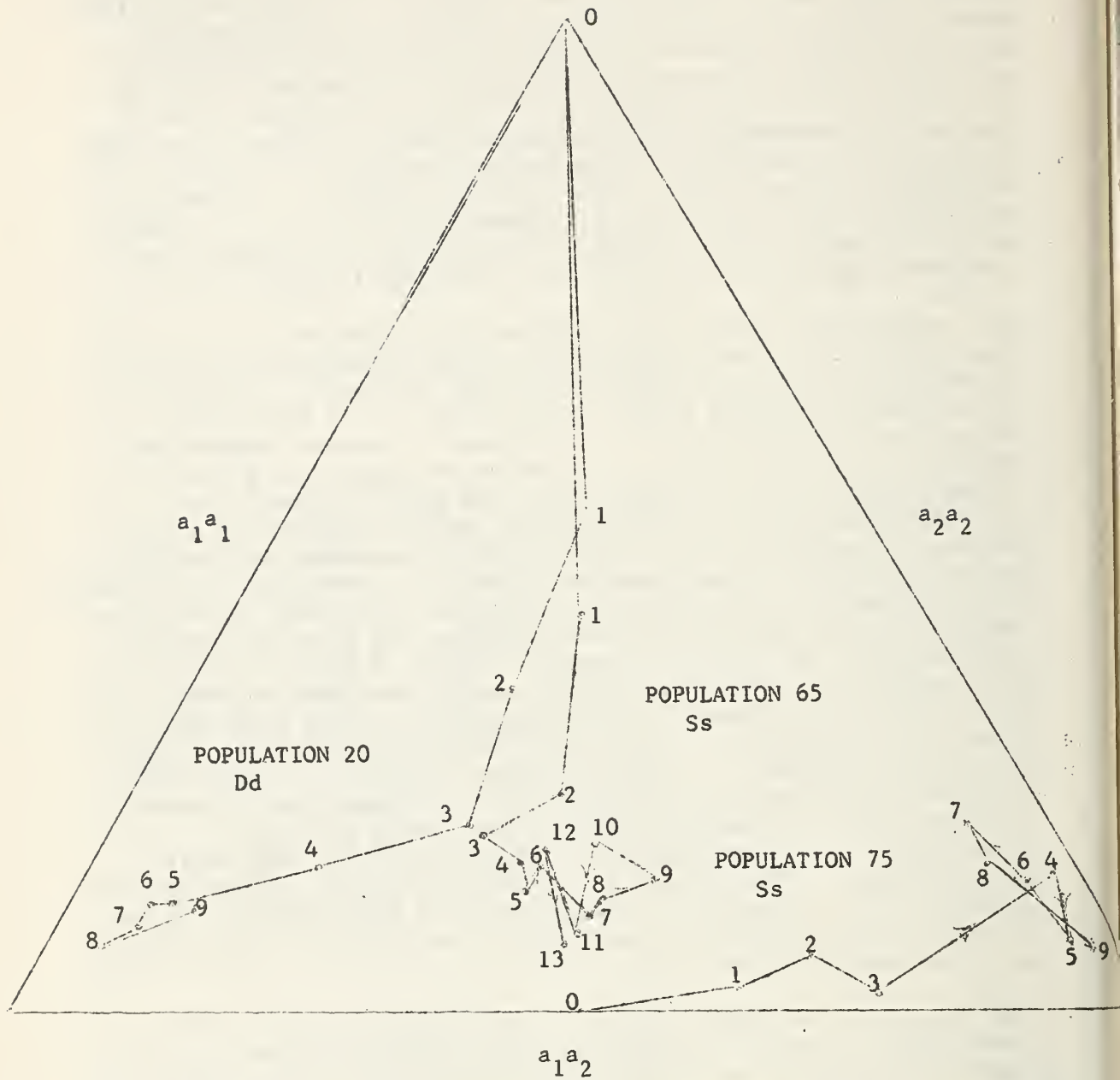


Figure 1.--Trilinear diagram showing observed frequencies of homozygotes (a_1a_1 , a_2a_2) and heterozygotes (a_1a_2) for the $\underline{S}/\underline{s}$, $\underline{D}/\underline{d}$ and $\underline{S}/\underline{s}$ loci in lima bean Population 65, 20, and 75, respectively. Note that Population 75 was synthesized by mixing equal proportions of $\underline{SS}$ and $\underline{ss}$ homozygotes. Triangles show population points in generations 10-15 for additional marker genes in other lima bean populations.

genotypic frequencies the average fitness of the population will be $\bar{W} = \sum f_i w_i$. The mean fitness of a population so defined will vary with genotypic constitution. It will be low if poor genotypes are frequent, high when the most fit genotypes predominate, and it can be shown that gene and/or genotypic frequencies will change so as to maximize mean population fitness.

As noted above, genotypic frequencies of the marked segments illustrated in figure 1 changed rapidly in early generations and thereafter drifted indecisively about apparent equilibrium points. The approximate equilibrium points ($f_1:f_2:f_3$) are (.46:.12:.42), (.83:.09:.07) and (.82:.13:.05) for the S/s, D/d and S/s segments in populations 65, 20, and 75, respectively. The fitness values required to produce these equilibrium points in populations for which $s = .95$ are given in table 1. Estimates of the fitness values can also be computed from the ratio of the number of individuals observed to the number expected (Haldane, 1956; Lewontin and White, 1960), or from generation-by-generation changes in genotypic frequencies (Allard and Workman, in press). Since these three methods give essentially the same results, we shall consider here only the estimates given in table 1, which were computed from the equilibrium frequencies.

Table 1.--Adaptive values of the two homozygotes (w_1, w_3) and the heterozygote (w_2) for three marker loci in lima bean populations.

	w_1	w_2	w_3
<u>S/s</u> population 65	0.66	1.00	0.66
<u>D/d</u> population 20	0.58	1.00	0.47
<u>S/s</u> population 75	0.53	1.00	0.35

If the fitness of the genotypes are constant and independent of their frequencies, mean population fitness can be calculated for any gene frequency. When fitness curves were computed for each generation it was found that, by generation 3 or 4, the population point had moved to or near the adaptive maximum predicted from the selective values of the genotypes. Thereafter the shape of the curve and the position of the population point fluctuated some from generation-to-generation but the population point and adaptive peak were rarely far apart. The curves for populations 65, 20, and 75 in generation 10 are given in figure 3.

For the S/s locus in population 65, the adaptive peak occurs near $q = .5$. However, the flatness of the fitness curve raises doubts concerning the stability of the equilibrium. The adaptive peaks are much more definite for the D/d and S/s segments in population 20 and 65. Nevertheless the equilibria appear to be precarious in both cases

such that the advent of one or more seasons in which the selective advantage of the superior homozygote increases, or the advantage of the heterozygote over both homozygotes decreases, or the amount of outcrossing decreases, might lead to fixation of D and S.

To check the probable future of these segments we have conducted a number of simulations of these systems on a digital computer. Since the computer simulations (figure 2) correspond closely to observed changes (figure 1) for the generations for which observations were available on the actual populations, the simulations appear to be useful for prediction of the future genetic history of these populations. In the simulations fixation did not occur within 40 generations in any of the three cases when selective values were made constant from generation to generation. This was also the case when the selective values were allowed to fluctuate about the mean, generation by generation, with standard deviation $\sigma_w = 0.10$ (Allard and Workman, in press). It therefore appears that the populations are likely to remain genetically variable with respect to these segments for an indefinite number of generations.

The three segments discussed above (especially S/s in population 65) were selected for discussion because they illustrate the most commonly occurring types of fitness curves for the 30 or so marked segments which have been studied to date in various species (especially lima beans, barley, and wheat). Since the marker loci were chosen for study solely on the basis of ease and accuracy of classification, there is no reason to believe that they represent special cases with respect to selective values. Apparently, therefore, the fitness of homozygotes and heterozygotes in predominantly self-pollinated populations commonly assume numerical values that permit indefinite maintenance of genetic variability.

B. Two "Locus" Cases

When two pairs of marked segments are considered simultaneously the situation becomes more complex because interaction between the pairs of segments may influence the fitnesses of the genotypes. Observed frequencies for three representative cases involving non-linked pairs of marker loci are given in table 2. Chi-square tests based on deviations from proportionality of marginal frequencies indicate independence of the fates of the C/c - D/d and V/v - D/d segments. However, interaction almost certainly exists ($P < .001$) for the P/p - R/r segments such that the PPRR and pprr genotypes have higher and the PPrr and pPRr genotypes have lower viabilities than expected under additivity.

Table 2.--Composition of lima bean population 54 in F_{10} , with deviations from proportionality of marginal frequencies

	DD	Dd	dd
CC	275 (-4.95)	42 (-2.29)	100 (7.24)
Cc	36 (3.78)	6 (0.90)	6 (-4.68)
cc	24 (1.17)	5 (1.39)	5 (-2.56)
	$\chi^2 = 4.89$	$P = 0.30-0.50$	
	DD	Dd	dd
VV	179 (-5.82)	31 (3.82)	55 (2.00)
Vv	38 (-5.94)	9 (2.54)	16 (3.40)
vv	191 (11.76)	20 (-6.36)	46 (-5.40)
	$\chi^2 = 6.39$	$P = 0.20-0.30$	
	RR	Rr	rr
PP	53 (18.59)	12 (-2.79)	44 (-15.80)
Pp	17 (-1.07)	17 (9.23)	18 (-8.16)
pp	44 (-17.52)	20 (-6.44)	113 (23.96)
	$\chi^2 = 42.16$	$P < 0.001$	

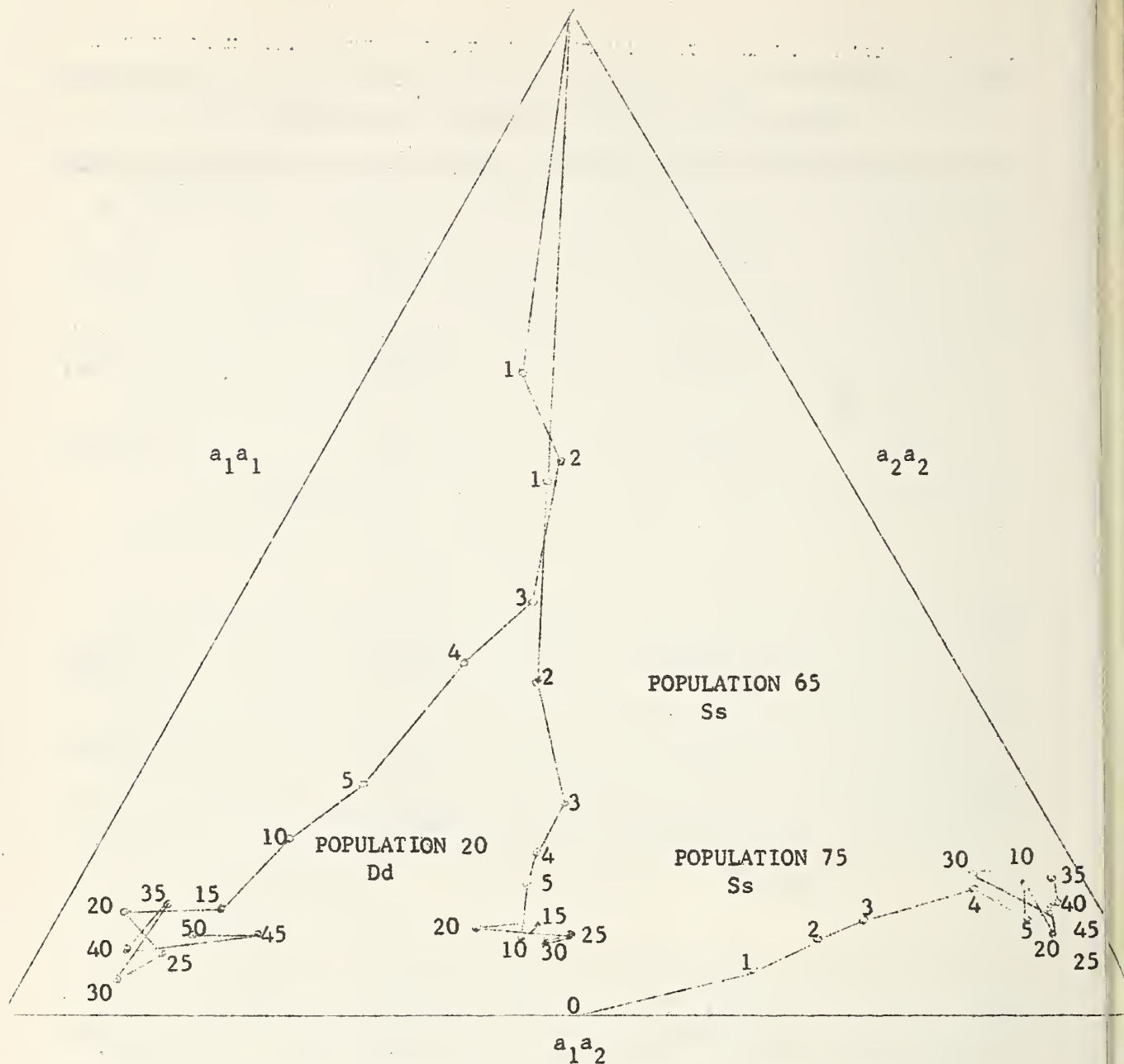


Figure 2.--Computer simulations of the populations of figure 1. Season-to-season fluctuations in adaptive values (table 1) were assumed to be normally distributed about the means with $\sigma_w = 0.10$. Population size was 200.

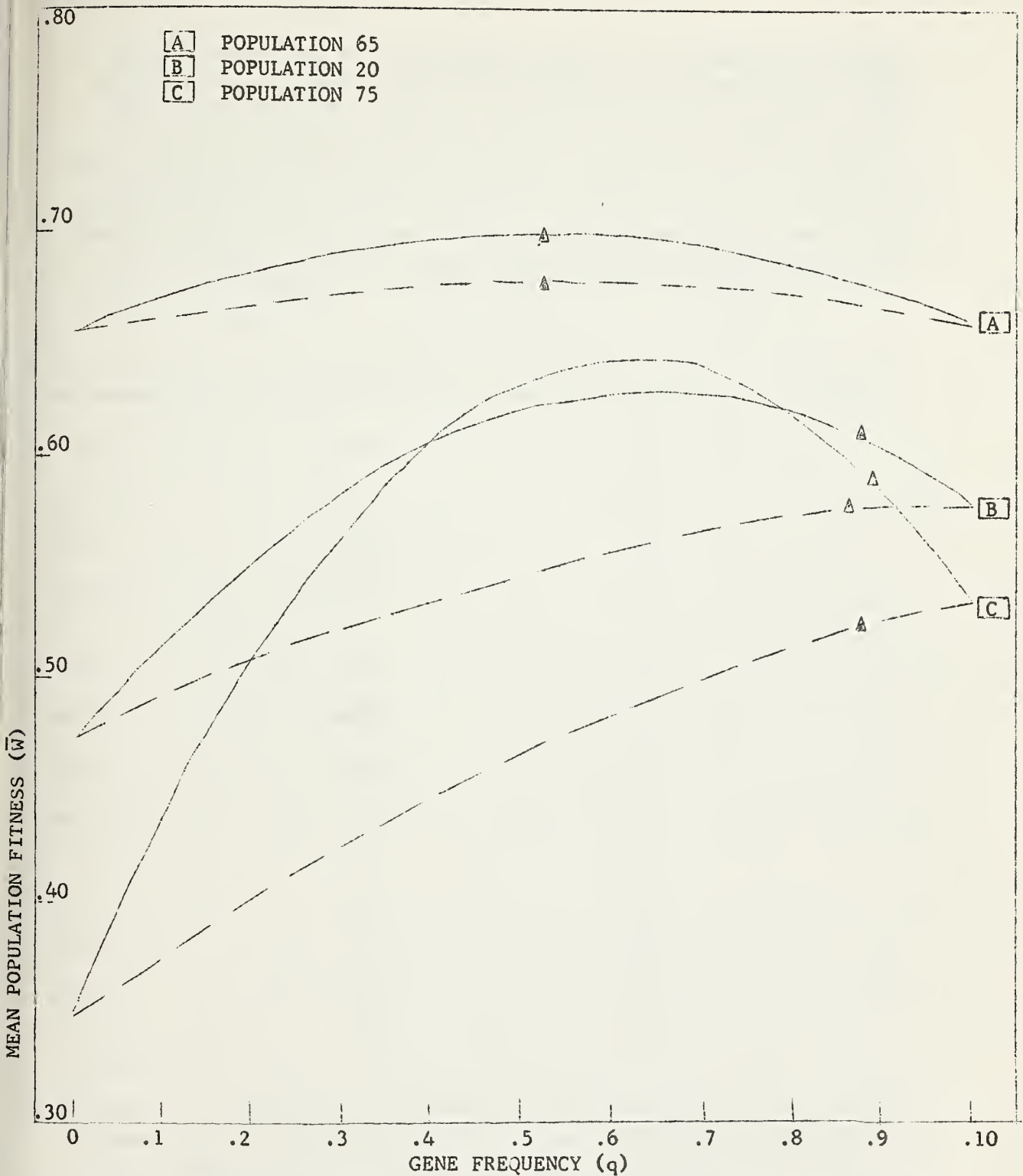


Figure 3.--Curves representing mean population fitness ($\bar{w}$) for the populations of figure 1. The dashed lines were calculated on the basis of the theoretical F value for $t = 0.05$ and represent the status of the population immediately after fertilization. The solid lines were calculated on the basis of realized F values and represent the status of the populations after the less fit genotypes have been reduced in frequency by natural selection. The black dot on each curve represents the population point.

The relative viabilities of the 9 genotypes formed by each pair of segments were estimated by methods parallel to those employed in the single locus cases discussed earlier. Since, however, many of the genotypes occurred in low frequency and the sample was not large, the estimates obtained were somewhat erratic. In particular, estimates made from the ratio of numbers observed to numbers expected gave distastefully high fitness values for single and double heterozygotes. I have consequently not accepted the fitness values obtained with any single method of estimation but have taken all three methods into account in arriving at the somewhat idealized values given in table 3.

Table 3.--Estimated relative viabilities for three pairs of marker loci in population 54.

	DD	Dd	dd
CC	.595	.784	.577
Cc	.811	1.000	.794
cc	.535	.724	.504
	DD	Dd	dd
VV	.663	.842	.644
Vv	.821	1.000	.803
vv	.663	.841	.644
	RR	Rr	rr
PP	.386	.568	.293
Pp	.593	1.000	.606
pp	.299	.591	.401

Assuming that the fitnesses of the genotypes are constant and independent of their frequencies, mean population fitness ($\bar{W}$) can be calculated for any combination of frequencies for the pairs of marked segments by an extension of the procedure used in the single locus cases. $\bar{W}$ can be put in the form of an adaptive surface or topography in which the two horizontal dimensions represent the frequencies (q_1 and q_2) for the two loci and the vertical distance at each point represent the mean fitness. While only one adaptive peak is possible for the one locus case, three are possible for two loci (Moran, 1963) and with many loci an indefinite

number of peaks can exist. Thus an "adaptive landscape" is formed with peaks, valleys, ridges, and saddles and in any generation the population can be represented by a point corresponding to the "gene" frequencies, q_1 and q_2 (Lewontin and White, 1960). The trajectory of change in genotypic frequencies will be such that the population point will progress up the nearest peak, taking the route of steepest slope, until it rests on the peak of local influence. At this point the Δq_1 , Δf_1 , and $a\bar{w}/aq_1$ and $a\bar{w}/af_1$ will be zero, i.e., the population will be in equilibrium. Thus populations might come to rest at equilibrium genotypic frequencies which do not correspond to the maximum fitness for the entire topography.

In studies of numerous two "locus" cases a variety of such adaptive landscapes have been observed. Those corresponding to the fitness values given in table 3 illustrate three commonly observed types. The topography for $\underline{D}/\underline{d} - \underline{V}/\underline{v}$ (figure 4A) has a single nearly central peak and that for $\underline{C}/\underline{c} - \underline{D}/\underline{d}$ (figure 4B) is also single peaked but the peak is located near one margin. The observed population point lies near the adaptive peak in both cases. A number of computer simulations of these systems have corresponded closely to observed changes in the actual populations, suggesting that the estimates of the relevant population parameters are reasonably accurate. The discrepancies which occur between the actual populations and the simulations were in a direction suggesting that the degree of heterozygote advantage, as given in table 3, was slightly underestimated, or that the selective value of one of the homozygotes was over-estimated slightly, or that selective values are not entirely independent of gene frequencies such that the disadvantage of the inferior homozygote becomes less as its frequency decreases in the population. The computer runs were continued for 50 generations, and since fixation did not occur, we assume that population 54 is in reasonably stable equilibrium respecting the $\underline{V}/\underline{v} - \underline{D}/\underline{d}$ and $\underline{C}/\underline{c} - \underline{D}/\underline{d}$ segmental pairs. Typical computer runs are superimposed on the adaptive topographies (figures 4A and 4B).

The topography for $\underline{P}/\underline{p} - \underline{R}/\underline{r}$ (figure 4C) presents a different picture, as might be expected from the interaction (table 2) between these segments. There is a ridge of high fitness running from the upper left to the lower right hand corner of the topography. This ridge is a result of the relatively high fitness values of the PPRR and pprR homozygotes. On either side of the ridge the surface falls away steeply due to the low fitness values of the PPrr and ppRR homozygotes. In F_{10} (figure 4C) the middle of the ridge is slightly higher than the ends, forming a low adaptive peak. However, in generation F_7 , when the realized F value was slightly higher, and in generation F_9 , when the selective advantages of the heterozygous genotypes were slightly lower than in F_{10} , the middle of the ridge was lower than the ends and the low adaptive peak was replaced by a shallow saddle. The population point in the actual populations, and in all computer runs based on parameters estimated from the F_{10} data,

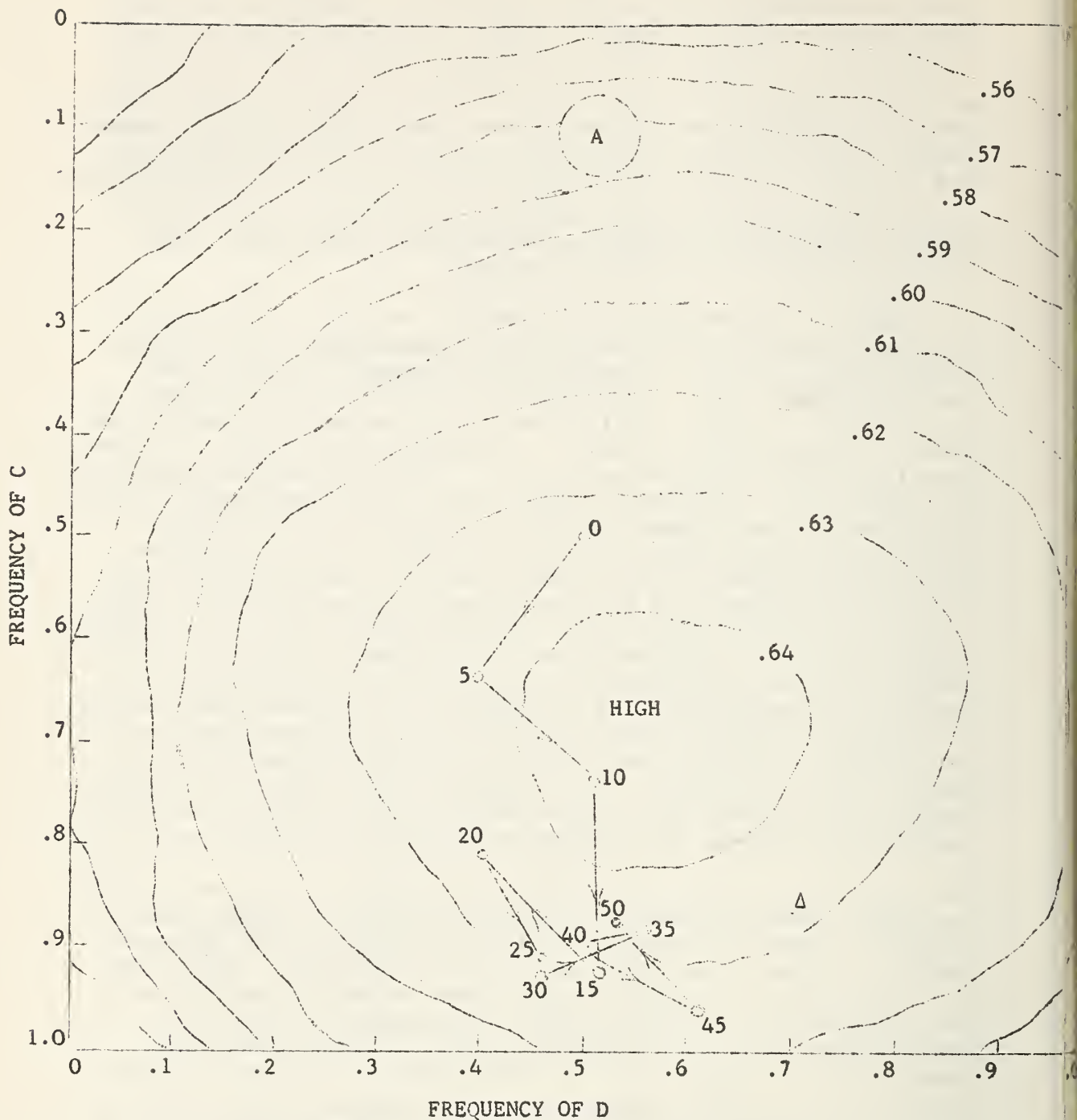


Figure 4A.--Adaptive topography for Population 54 (F_{10} generation) computed on the basis of fitness values given in table 3. The triangle represents the observed population point. A typical computer simulation (50 generations) is superimposed on the topography.

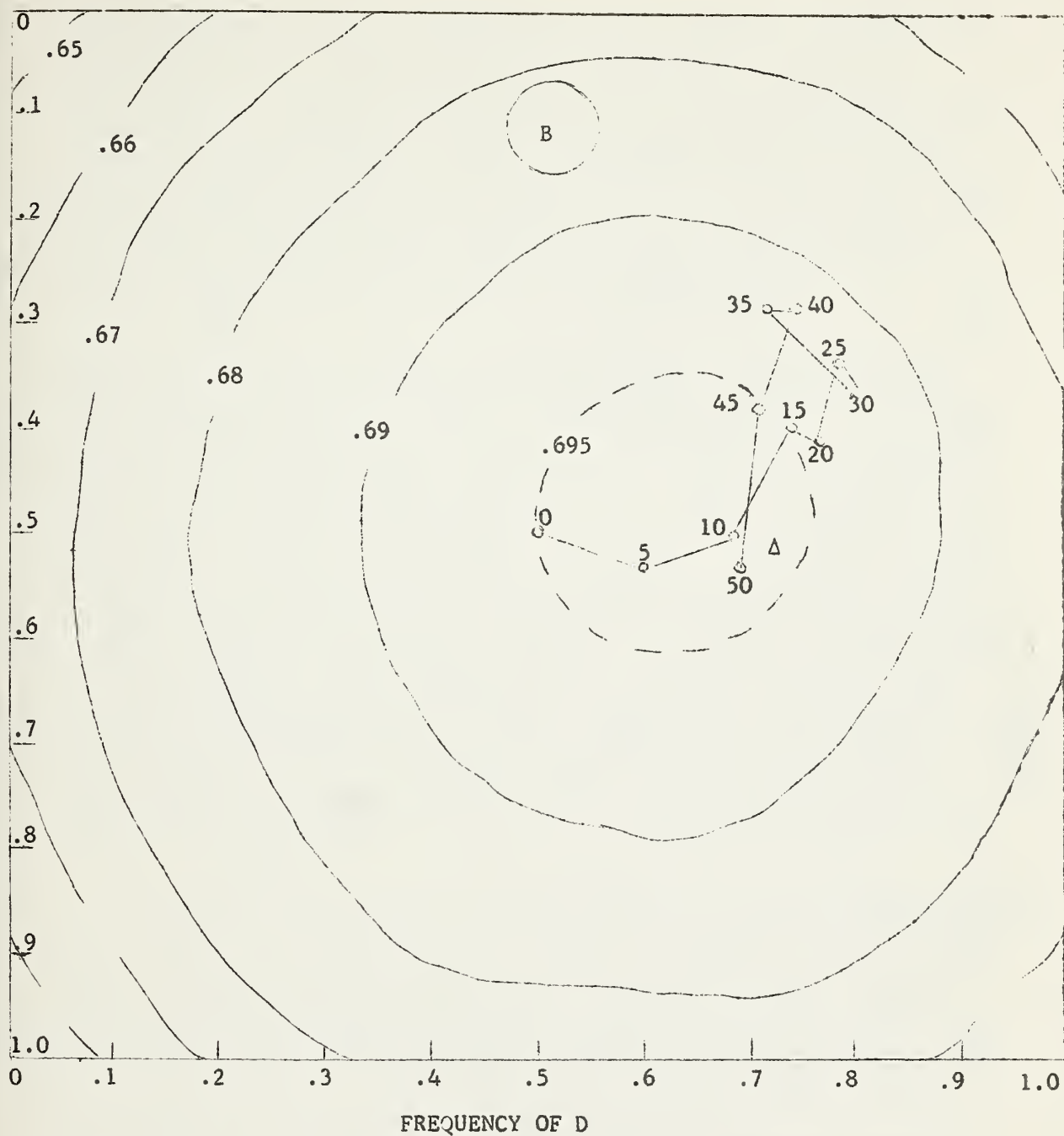


Figure 4B.--Adaptive topography for Population 54 (F_{10} generation) computed on the basis of fitness values given in Table 3. The triangle represents the observed population point. A typical computer simulation (50 generations) is superimposed on the topography.

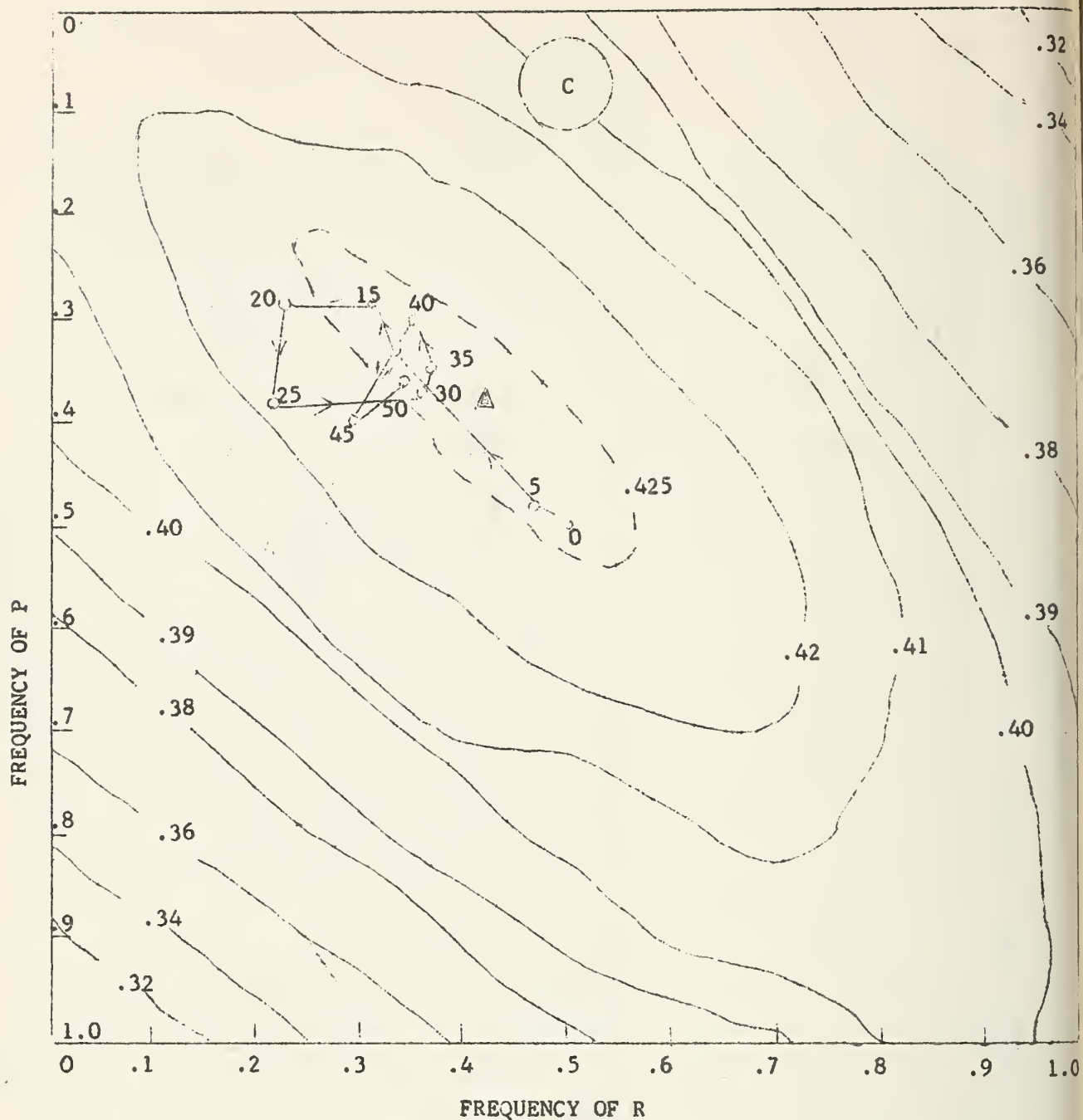


Figure 4C.--Adaptive topography for Population 54 (F_{10} generation) computed on the basis of fitness values given in table 3. The triangle represents the observed population point. A typical computer simulation (50 generations) is superimposed on the topography.

were coincident with the position of the peak. However, computer runs based on the slightly different estimates which lead to the saddle configuration frequently approached fixation for pprr in generation 50. Apparently Population 54 is in precarious balance respecting equilibrium for the P/p - R/r segments such that a slight decrease either in the amount of outcrossing or in the advantage of heterozygotes might lead to fixation. The nature of the interaction between these marked segments therefore appears to jeopardize maintenance of heterozygosity for these segments since the fitness values of P/p and R/r considered separately take numerical values that are expected to permit highly stable equilibria.

The situation as it has been discussed thus far can be summarized as follows. The genetic composition of predominantly self-pollinated populations approximates to what one expects if the amount of selfing versus outcrossing and the selective values of the various genotypes are both taken into account. Two attributes of the selective values deserve special emphasis. These are, first, the high proportion of cases in which the heterozygote has selective advantage over both homozygotes and second, the common occurrence of interactions between marker loci. Other factors which appear to have lesser effects on population structure are year-to-year fluctuations in fitness values and mating system, gene frequency dependent selection, and population size (so long as N is reasonably large). Thus, while self-fertilization is a powerful force in determining the course of genetic change in predominantly selfing populations, it is not the only important factor affecting the structure of such populations, as has commonly been supposed. Accurate description of populations requires that factors other than mating system be taken into account and among these other factors fitness values of the various genotypes are by far the most important.

III. The Genetic Structure of Predominantly Self-Pollinated Populations.

In this section we shall attempt to answer two questions: (1) What predictions can be made regarding the fate of various sorts of populations of finite size with respect to n loci simultaneously, if we generalize from population parameters estimated from one and two "locus" cases?; (2) Are these predictions consistent with observations on actual populations? In attempting to answer these questions we shall emphasize rates and duration of release of genetic variability and the effects of natural selection in changing fitness and yield in successive generations.

To evaluate expected rates of release of genetic variability and the expected genetic composition of finitely sized multilocus populations, a computer program has been written which takes into account the following: (a) the initial status of the population; (b) the mating system; (c) population size; (d) fitness values of the genotypes; (e) linkage between loci; and (f) random environmentally induced fluctuations in mating system and fitness values. This program has been used to simulate various hypothetical populations in which the

relevant population parameters were given values suggested by the analyses of one and two locus cases such as those discussed earlier. The items recorded each generation were the amount of selfing versus outcrossing actually achieved, amount of crossing over which occurred, and some other items relevant to checking the program. Also recorded were the genotypic frequencies of the two homozygotes and the heterozygote averaged over all loci, the number of different genotypes in the population, the mean length of chromosome sequence as constituted in the parents, and mean population fitness. A sample of the results are given in figures 5-7.

The results depicted in figures 5-7 are based on a hypothetical organism assumed to have a single chromosome with 10 loci spaced 10 crossover units apart. Populations were assumed to consist initially either of the heterozygote $\frac{0000000000}{1111111111}$, or of equal proportions of the two homozygotes $\frac{0000000000}{0000000000}$ and $\frac{1111111111}{1111111111}$, or $\frac{1010101010}{1010101010}$ and $\frac{0101010101}{0101010101}$. Population size was made constant at $N = 500$ and the amount of outcrossing, t , was either 1.0 or 0.05. Fitness values ($w_1:w_2:w_3$) were assigned so as to represent equality of all three genotypes (1:1:1) at each locus, or various mean levels of symmetrical (.98:1:.98), (.75:1:.75), (.60:1:.60) or asymmetrical (.85:1:.80) homozygote disadvantage.

The number of genotypes occurring in such populations in generations 1-40 are plotted in figure 5. In generation 1 populations made up by mixing homozygotes obviously include only two genotypes. In generation 2 this number increases to three genotypes (so long as $t > 0$) and subsequently, as a result of further outcrossing, segregation and recombination, the number of genotypes increases further. The number of genotypes obviously cannot exceed 500 at any one time in a population of size 500, although it is possible over a number of generations that all of the $3^{10} = 59,049$ genotypes may have been present at one time or another. With panmixia ($t = 1.0$) the maximum of 500 genotypes was approached closely within 10 generations regardless of fitness values and initial composition of the population. However, with heavy inbreeding ($t = 0.05$) the number of genotypes was, as expected, affected both by selective values and the initial status of the population. When all loci were selectively neutral ($w_1 = w_2 = w_3 = 1$), the number of genotypes increased from 2 to an apparent equilibrium number of about 100 by generation 15. With slight heterozygote advantage ($w_1:w_2:w_3 = .98:1:.98$) the number of genotypes was substantially higher and assumption of heterozygote advantage equivalent to that commonly observed in actual populations ($w_1:w_2:w_3 = .75:1:.75$ or $.60:1:.60$) leads to hypothetical populations in which few genotypes were represented twice.

As expected, directional selection, initial composition of the population (homozygous versus heterozygous), and the original makeup

Figures 5, 6, and 7.--Numbers of genotypes (figure 5), mean length of parental sequence (figure 6), and percent heterozygosis (figure 7) in hypothetical computer populations (see text). Mean fitness values ($\bar{W}_1:\bar{W}_2:\bar{W}_3$) are: A, B, C (1:1:1); D (.98:1:98); E (.75:1:.75); F (.60:1:.60); G, H (.80:1:.85). Mean outcrossing $t = 0.05$, except $t = 1.0$ (panmixia) for Curve C. Curve B represents an originally heterozygous population. In all other cases the initial population was assumed to consist of equal proportions of the homozygotes $\frac{0000000000}{0000000000}$ and $\frac{1111111111}{1111111111}$ except G where the initial population was assumed to consist of equal proportions of the homozygotes $\frac{1010101010}{1010101010}$ and $\frac{0101010101}{0101010101}$. Under directional selection 1 was assumed to be the superior and 0 the inferior allele. Percentage of heterozygotes was slightly more than 50 under panmixia, presumably as a result of drift associated with finite population size ($N = 500$). Drift affects other results similarly.

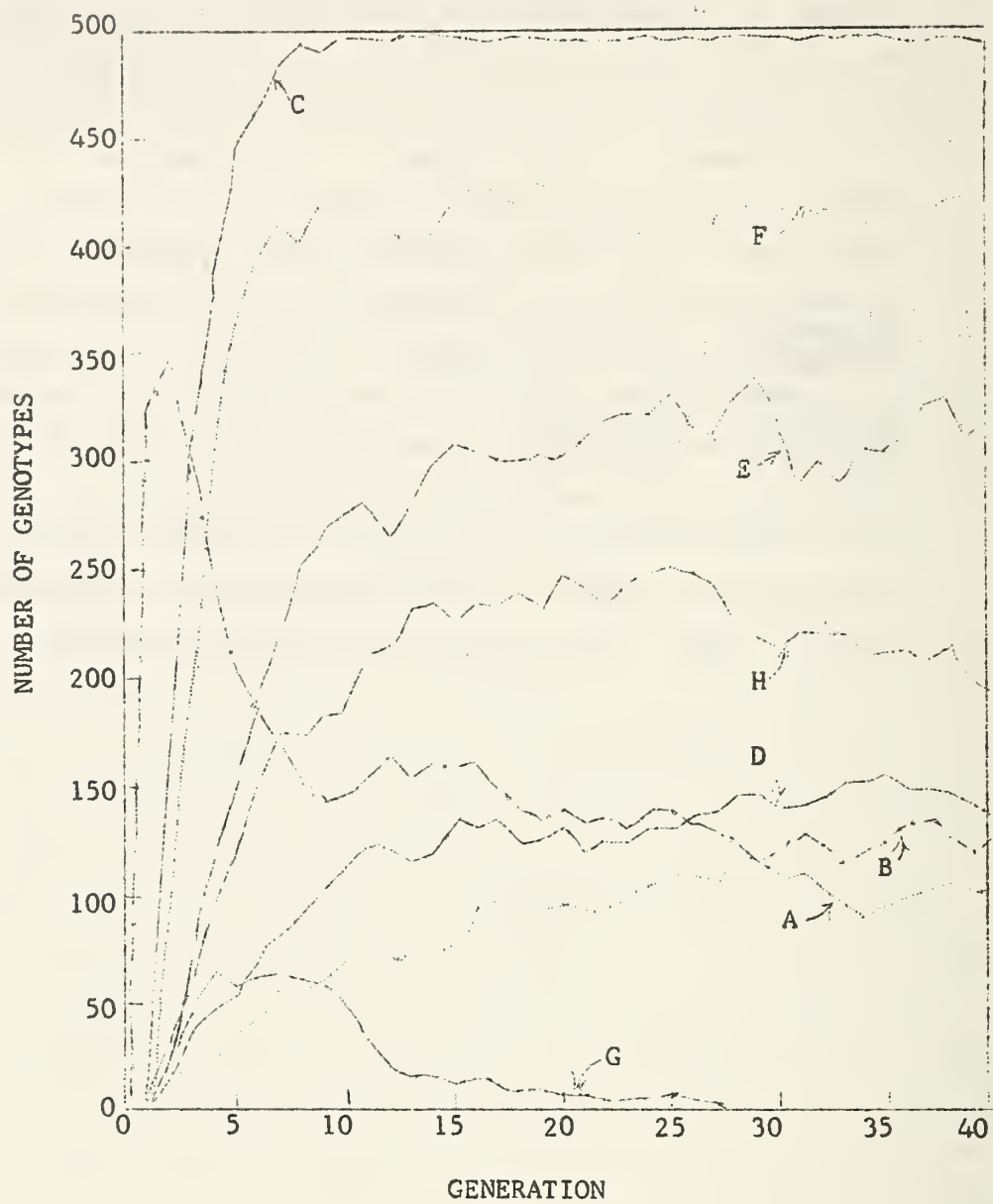


Figure 5.

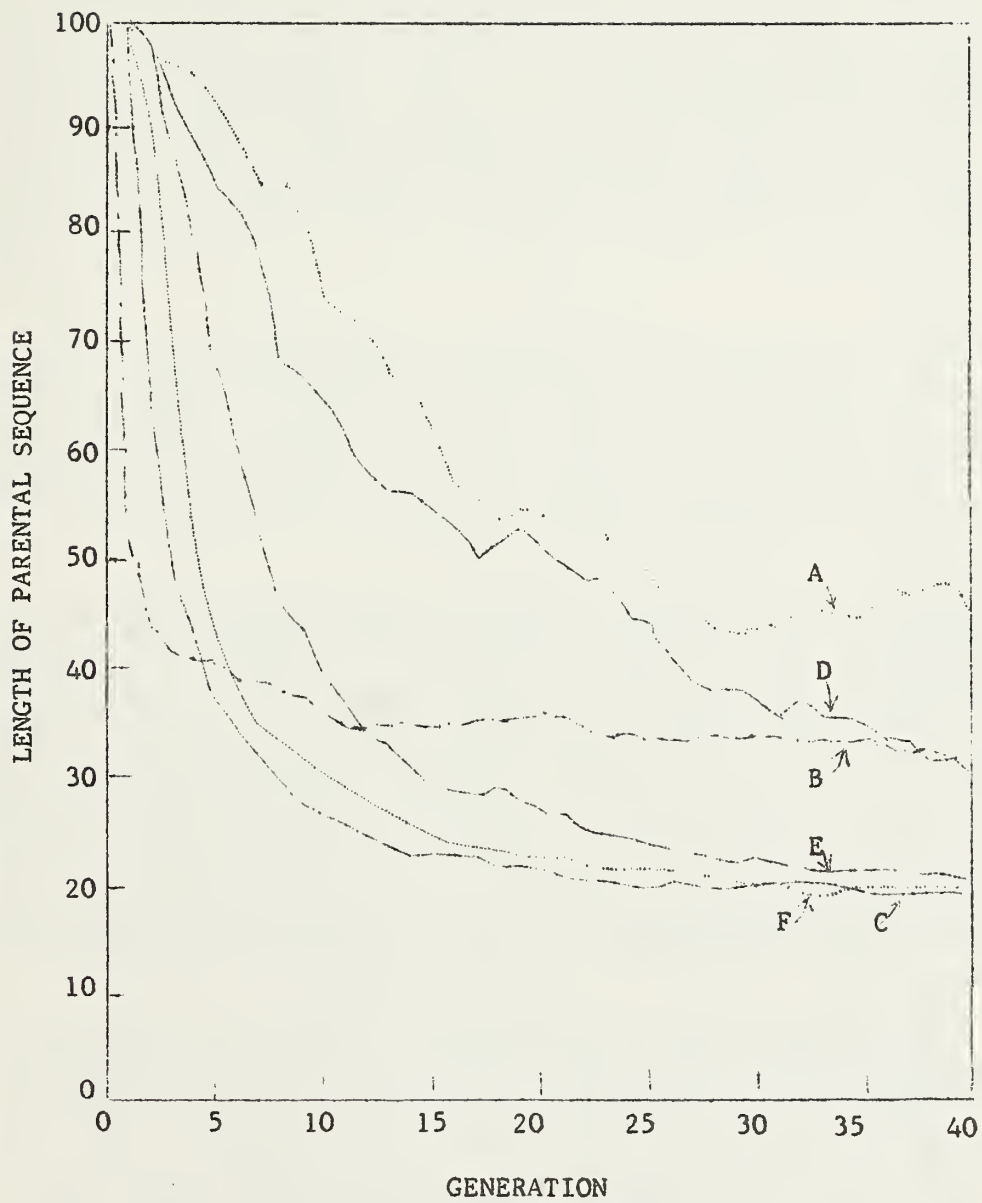


Figure 6.

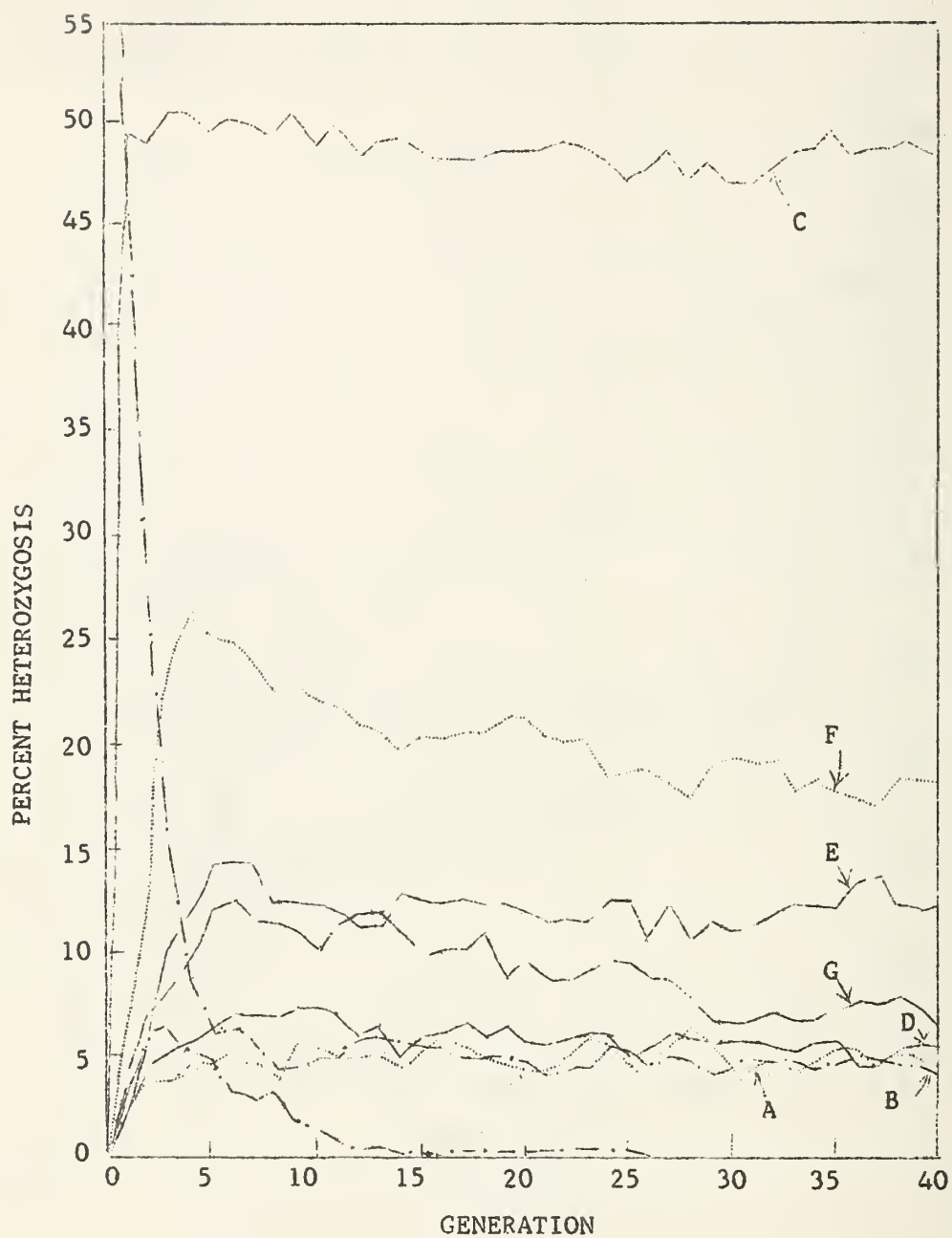


Figure 7.

of the chromosome (0000000000 or 1111111111 versus 1010101010 or 0101010101) affect variability as measured by numbers of genotypes (figure 5).

The above hypothetical cases are almost certainly much less complex than real populations. For example, it is likely that the parents in any real population will differ by many more than 10 genes per chromosome. Also, since linkages both closer and looser than 10 crossover units must occur in real populations, both more rapid and longer continued release of variability is expected than in our hypothetical populations. Thus, in a species such as the lima bean, which has 11 pairs of chromosomes, it seems likely that almost every individual in a population consisting originally of two or more homozygotes will differ genetically from each other individual within a few generations, even though the species is 95 percent self-pollinated.

In figure 6, I have plotted, for these same hypothetical populations, the mean length of chromosome sequence as constituted in the parents. If the sequence of alleles in the parents is designated 1111111111 and 0000000000, the mean segmental length is 100 crossover units originally but thereafter becomes shorter as a result of crossing over and recombination. Thus mean segmental length provides a measure of the rate of release of genetic variability.

Figure 6 shows that original sequence length of 100 is reduced to the theoretical value (for our model) of 18 units within a few generations in panmictic populations, irrespective of specifications regarding fitnesses of the various genotypes. With 95% selfing the rate of breakup of parental sequences is slowest when viabilities of all genotypes are set equal and increasingly rapid with increase in heterozygote advantage. However, even for $w_1 = w_2 = w_3 = 1$, the mean length of sequence has been reduced to approximately 50 units by generation 20, and to 40 units by generation 40. These results suggest that the recombination rate may be ample, even under low levels of outcrossing, to provide for reasonably rapid release of variability due to breaking of linkages.

The mean percentage of heterozygosis for these hypothetical populations is plotted in figure 7. The results make clear one striking difference between inbreeding and outbreeding populations, namely that irrespective of extent of heterozygote advantage (within the range of values observed in actual populations), heterozygosity is much higher in outbreeders than in inbreeders. Even though inbreeding populations may be nearly as variable genetically as outbreeding populations, much more of the variability in the former is held in homozygous genotypes. Thus the two mating systems, at least in their more extreme forms, lead to quite different population structures. These results therefore suggest that inbreeding and outbreeding species may be differentiated, not so much by differences in total amounts of genetic variability as is commonly believed, but as a result of the manner in which similar amounts of variability are held in populations.

A. Observations on Actual Populations

In this section we shall consider whether the predictions of the previous section are consistent with the genetic changes which have been observed in actual populations with respect to metrical characters. We shall consider in turn changes in observed mean and variance for a typical metrical trait (heading time in barley Composite Cross V), the distribution of genetic variability between and within families respecting this trait, observed changes in fitness (measured as numbers of seeds produced) in this barley population, and finally changes which have been observed in the yielding abilities of representative populations in various species.

Figure 8 illustrates changes which occurred in heading time from F_3 to F_{19} in Composite Cross V (Allard and Jain, 1962). Mean values changed steadily in the direction of earliness, indicating that directional selection operated on this trait. Although variance decreased slowly, showing that stabilizing selection was also occurring, the population remained highly variable with respect to heading time. These observations, which are representative for many metrical characters which have been studied, are consistent with the prediction that predominant self-fertilization (99% in Composite Cross V) does not necessarily lead to genetic uniformity in originally variable populations.

Estimates of between family variances for heading time for Composite Cross V, and for the original homozygous parents of this population, are given in figure 9. The between family variance was highest for the original parents, and in the Composite Cross population the variance decreased steadily from early to late generations. Thus, as the population became subdivided into families under continued inbreeding, steady selection apparently took place against the more extreme families. However, in F_{19} the between family variance (figure 9) was much larger than the mean within family variance of the parents (figure 10). Since the latter is an estimate of the environmental variance, it is apparent that great genetic diversity attributable to differences among families remained in the population in F_{19} . These results therefore support numerically the observation that no two familial isolates from the F_{19} generation of Composite Cross V look alike on visual inspection. Clearly a vast number of different genotypes remained in the population after 18 generations of exposure to natural selection, as expected from the predictions of the previous section.

The amount of variation within families in various generations is given in figure 10, from which it can be seen that within family variance decreased steadily from F_3 to F_{19} but remained larger in F_{19} than in the homozygous parents. This excess of variability over that of the parents appears to be best explained on the basis of residual

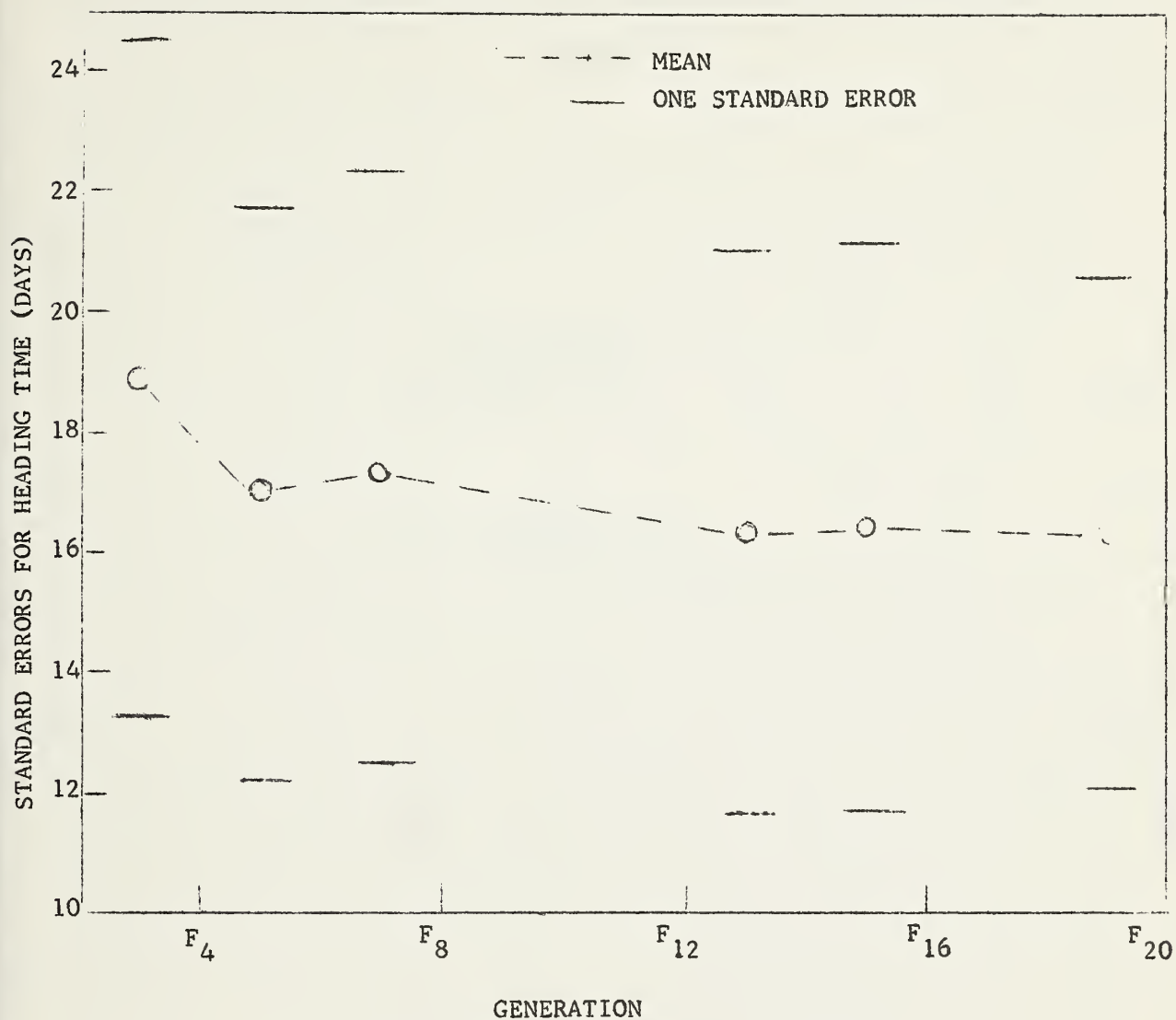


Figure 8.--Means and total phenotypic variability for heading time computed from measurements of individual random plant taken from barley Composite Cross V in various generations. (Adapted from Allard and Jain, 1962).

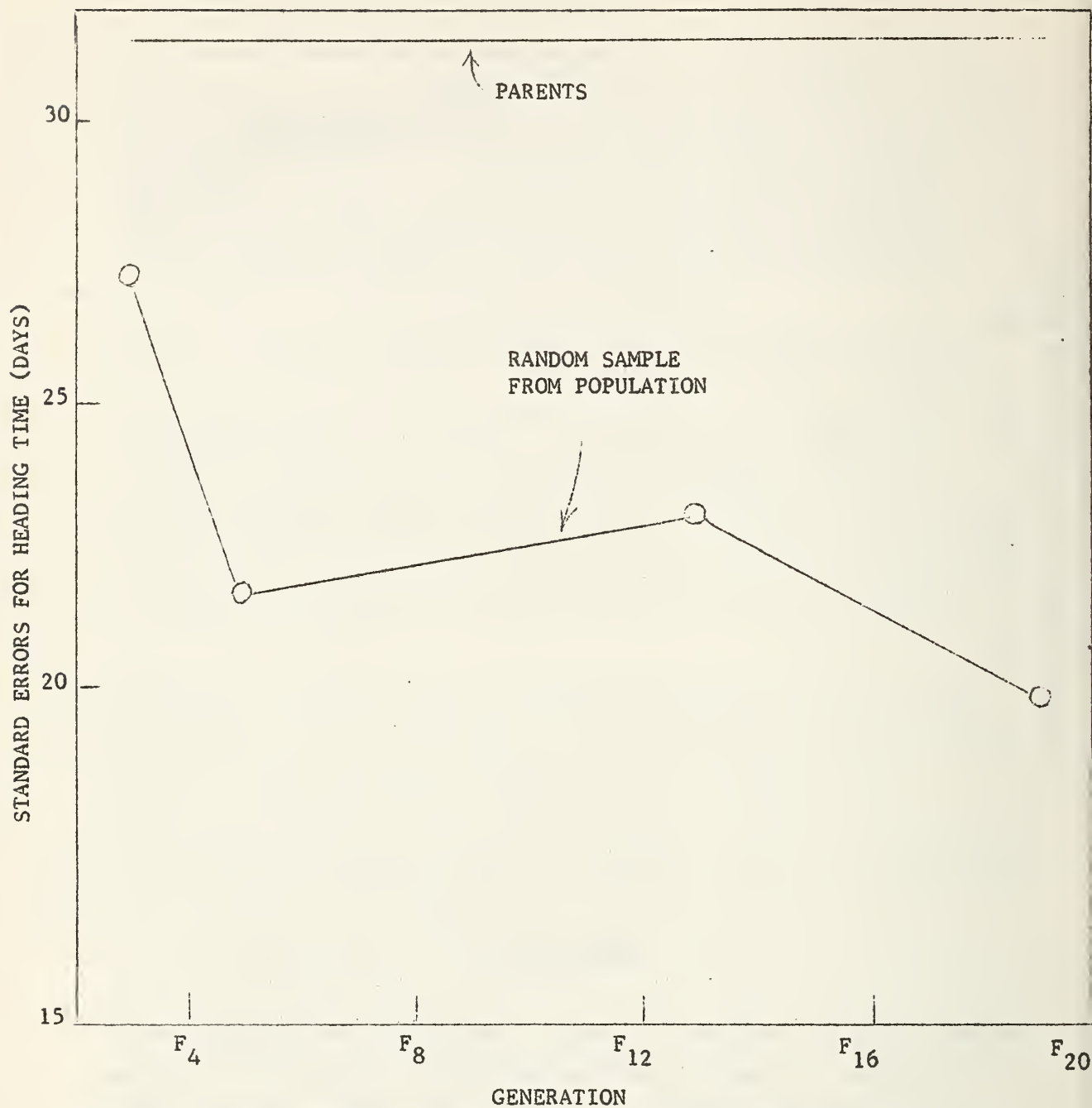


Figure 9.--Mean between family standard errors for heading time for the 31 homozygous parents of barley Composite Cross V, and for progenies of random plants drawn from the population in various generations. (Adapted from Allard and Jain, 1962).

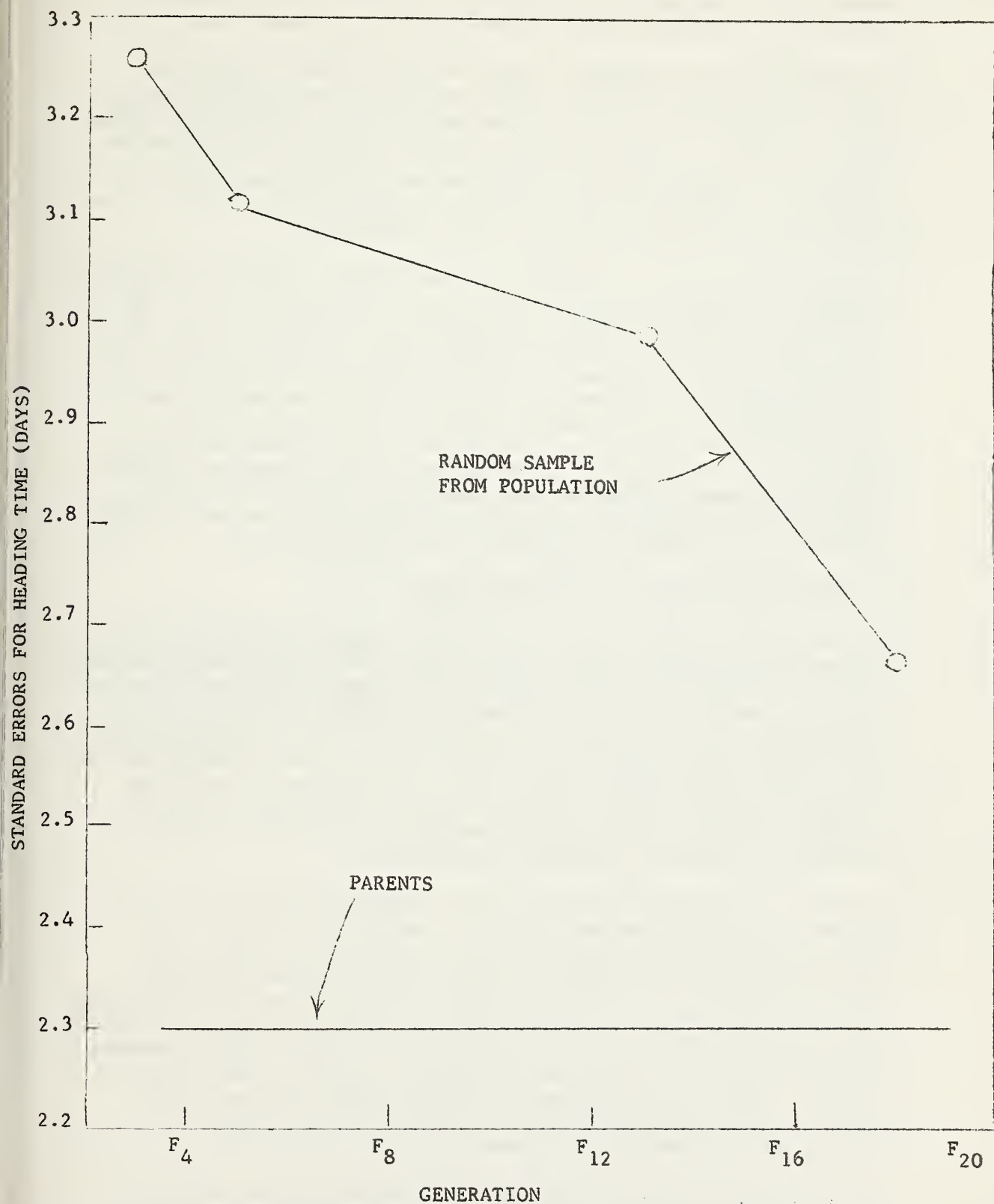


Figure 10.--Mean within family standard errors for heading time for the 31 parents of barley Composite Cross V and for progenies of random plants drawn from the population in various generations. (Adapted from Allard and Jain, 1962).

heterozygosity maintained by selection in favor of heterozygous segments of chromosome, again in conformity with prediction.

The experiment with Composite Cross V also provided information regarding changes in fitness of the population, measured as number of seeds produced per plant in various generations. Mean values showed steady increase in fitness from F_3 to F_{19} . Frequency distributions (figure 11) suggest that this increase was achieved mostly by elimination of inferior genotypes but also partly as a result of the appearance of highly fit types in later generations.

The yields of several representative populations, expressed relative to standard commercial varieties, are given in figure 12. In the early generations yields were conspicuously inferior to those of the standard varieties. This is perhaps not surprising since each of the populations was based on a conglomerate of adapted and unadapted parents. The fact that the yields of the populations increased rapidly in all cases provides evidence that natural selection is a powerful force in eliminating unadapted genotypes. Further, it seems unlikely, from considerations discussed earlier, that any of these populations have exhausted their potential for change. Hence they can be expected to give rise to new and original variants for an indefinite number of future generations.

IV. Some Implications in Plant Breeding

Earlier I have argued: (a) that breeding progress is often limited by the narrow genetic base of the materials with which plant breeders work; (b) that conventional breeding methods are often too expensive to exploit valuable genes from generally unadapted types; (c) that the breeder needs a continually replenished store of locally adapted variability for sustained progress and; (d) that mass reservoirs set up on a very broad genetic base could, in principle, provide the technique by which locally adapted recombinants might be obtained, at least in crops such as cereals and beans where seed yield and agricultural value are presumably correlated.

The idea of mass reservoirs of locally adapted variability is not new but has been stated implicitly or explicitly by Harlan and Martini, Suneson, Hutchinson, Harland, Harlan, and others. Only recently, however, have serious attempts been made to implement their widespread use. Notable examples are the proposals of Suneson and Wiebe (1962), who have made generally available a mass population based on 6200 barley strains, and Jensen (1962) who has recommended the formation of broadly based composites of wheat, barley, and oat hybrids. The studies reported here have a clear bearing on the probable future genetic history of such populations and on the breeding plans appropriate to them.

First it should be made clear that mass-reservoirs are not a substitute for any of the conventional methods of plant breeding.

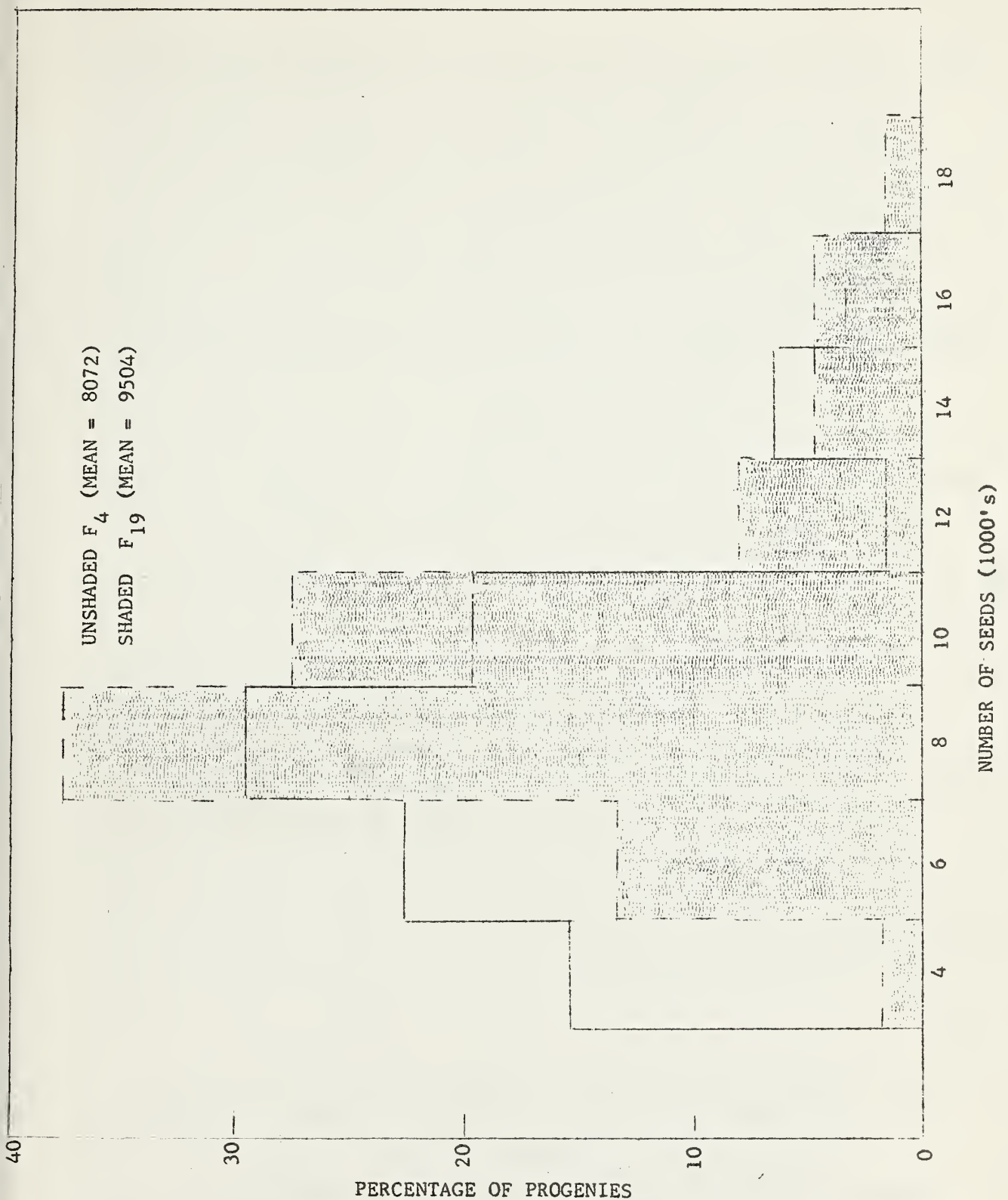


Figure 11.--Frequency histograms for number of seeds produced by progenies of random F_3 and F_{18} plants drawn from barley Composite Cross V in various generations. (Adapted from Allard and Jain, 1962).

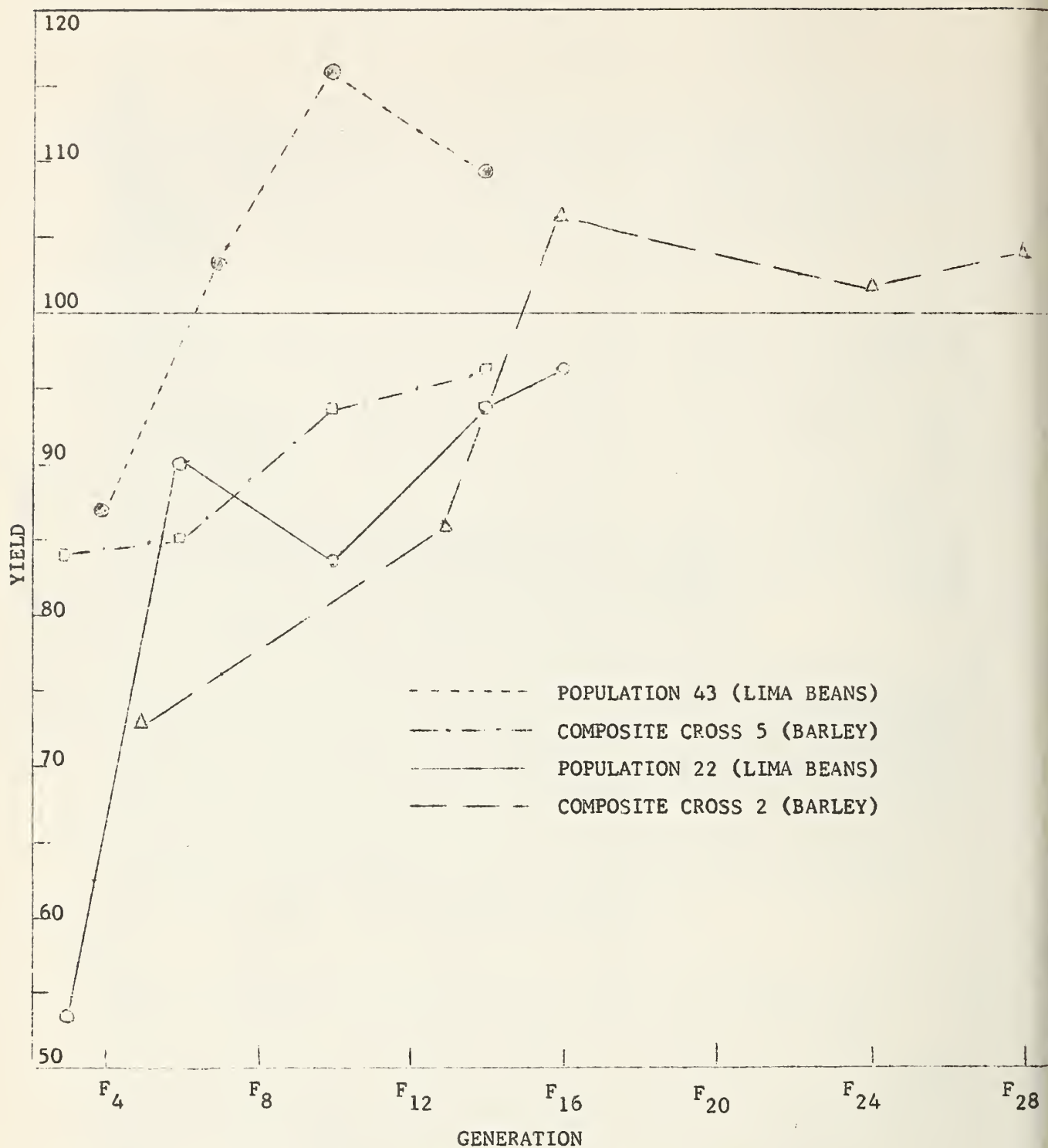


Figure 12.--Yield in various generations of four representative populations. Population yield is expressed as percentage of the yield of a standard adapted commercial variety.

In established crops nearly all of the entries of germplasm banks give performance inferior to locally adapted varieties. As parents, however, these unadapted strains sometimes make contributions which are unsuspected from their performance as varieties. Considering that most germplasm collections contain thousands of entries, the task of exploring each accession by conventional methods transcends the possibilities of conventional breeding methods. Mass reservoirs appear to offer an opportunity to explore the range of variability available in a species on a scale impossible by any other method by allowing the extraction of desirable genes from the entire range of genotypes existing in a species and making these genes available in reasonably well adapted genotypes. Thus, they are not to be thought of as a replacement for standard methods; instead they should be regarded as an additional breeding tool which provides a means of exploring and recombining a wide range of variability that would otherwise not be utilized. Their primary function is not to develop new highly adapted varieties, directly suitable for use in commercial production, but to provide reasonably adapted genotypes to be exploited by conventional techniques. The assumptions basic to their success in fulfilling this purpose are first, that mass reservoirs must be dynamic, giving rise continuously to new and original variants by segregation and recombination and second, that survival in mixture is correlated with agricultural value.

Evidence of two sorts is available concerning the dynamic nature of mass-reservoirs. Direct observation of a number of populations makes it clear that even heavily inbred populations (such as the barley composite crosses) include an enormous array of variants in the most advanced generations available for study. The weakness of this evidence is that only a few populations have been studied beyond the tenth or twentieth generation. This weakness has in part been overcome by identification and estimation of the effects of some of the forces affecting population structure. The present composition of the populations approximates closely to what one would expect from estimates of the mating system and estimates of the fitnesses of various genotypes. Predictions of the future of the populations, based on estimates of the relevant population parameters, suggest maintenance of a substantial degree of hybridity and continuation of recombination, with associated generation of new genotypes, for an indefinite period.

It has been generally assumed that the breeding plans appropriate to mass-reservoirs are closely dependent on the mating system of the species. Thus, while physical mixture of strains has been deemed adequate for outbreeders, and a single round of crossing adequate for frequently outpollinated species, polyallele or cyclical crosses have been recommended for heavy inbreeders to prolong the period of recombination. The use of male-steriles, or of recessive marker genes to identify natural hybrids, have been suggested to lessen labor and expense. An interesting implication of the present results is the doubt they throw on the necessity for anything more than mere physical mixture in setting up mass-reservoirs.

The evidence suggests that even an initial round of crossing is unnecessary (so long as maturity or other barriers do not prevent crossing under population conditions) for the creation of a dynamic recombinational system, even in species such as barley in which outcrossing rarely exceeds one percent. This is an important factor in a system in which low cost and low labor requirement are major features.

There is considerable evidence to suggest that survival of populations is usefully correlated with agricultural value. The extent of this correlation appears to be sufficient to virtually guarantee that any broadly based mass-reservoir will rapidly achieve performance superior to the average of the parents contributing originally to the populations. In fact the populations studied have, as populations, approached and sometimes exceeded in yield the best parents involved within 10 to 20 generations after their synthesis. Irrespective of the performance of the population as a whole, it is clear that enough agriculturally desirable types survive in unselected mixtures (Suneson, 1956) to make such populations rich sources of materials for sustained breeding progress. Moreover, should it become apparent at any time that aggressive but commercially inferior types are becoming predominant, it is usually possible to devise inexpensive artificial selection procedures by which the population can be guided in the desired direction without significant reduction in recombinational potential. For example, in lima beans we have been able to select for time of maturity by manipulating harvest time, for disease resistance by exposure to pathological organisms, for large seed size by use of screens, and for small plant size by rouging.

The economy and simplicity with which mass reservoirs of several thousand plants can be handled should be emphasized. Our mass-reservoirs of lima beans have sometimes been formed by simple physical mixture of the parental strains. In other cases recessive marker genes have been used to identify natural hybrids whose progeny are then harvested and bulked to initiate a mass reservoir. In still other cases the population has been based on hand-pollinated hybrids. Thereafter the populations have been handled with ordinary farm machinery, freeing the time of breeders involved for conventional breeding programs.

Conventional breeding programs in lima beans have suffered in the past from limitations imposed by inadequate numbers of adapted types available for use as parents. The lima bean in the north temperate zone traces back to a few introductions made more than 100 years ago and appears to be so narrowly based genetically that crosses between locally adapted types are capable of little response to selection, even in enormous progenies. At the same time more recent introductions are so ill-adapted that few of their progeny in crosses with adapted types approach commercial performance and exploitation of their potentialities by standard breeding procedures has been laborious and expensive. This problem appears to have been solved by the appearance of a virtual infinity of reasonably adapted and clearly novel types in some broadly based mass reservoirs started 10 to 15 years ago.

There has been one especially interesting and unexpected development in the program with the mass-reservoirs. Certain of them which were based on a limited number of generally well adapted parents have given performance superior to any of the parents and also superior to that of the best available pure-line commercial varieties. This superiority involves significant improvements in yield, maturity, and quality. The basis of this superiority is not yet clear but part of the answer may lie in heterosis associated with the persistent heterozygosity observed in similar populations. Part of the answer may also lie in the genetic heterogeneity of these populations, endowing them with what Lewontin (1959) calls mechanical homeostasis, and Simmonds (1962) calls specific and general population adaptation. This opens the possibility that optimum population structure for commercial varieties may not be achieved in pure-line varieties, or even through F_1 hybrid varieties.

Instead optimum population structure may be achieved by mixing compatible F_1 hybrids in those species in which hybrid varieties are possible, or through "synthetic varieties" in species where large scale production of hybrids is impractical.

Summary

Some of the factors which influence the genetic structure of populations of predominantly self-pollinated crop species were considered. Analyses of a number of one and two "locus" cases showed that the genetic composition of such populations approximates closely to what one would expect from knowledge of the mating system and from estimates of the mean fitnesses of the various genotypes. Selective advantage of heterozygotes over homozygotes appears to be a common feature in predominantly self-pollinated populations. Other factors with lesser influence on population structure include fluctuations in mating system and fitness values, gene frequency-dependent selection, interactions between loci and population size.

Computer simulations of n-locus situations based on estimates of the relevant parameters derived from experimental data indicate permanent maintenance of substantial hybridity and virtually indefinite continuation of recombination, with associated formation of new genotypes, even under high levels of selfing.

The implications of these results were considered regarding the utility of "mass-reservoirs" in providing the continuing supply of adapted variants necessary for sustained breeding progress and with respect to optimum population structure of commercial varieties.

Literature Cited

- Allard, R. W. and S. K. Jain. 1962. Population studies in predominantly self-pollinated species. II. Analysis of quantitative genetic changes in a bulk-hybrid population of barley. *Evolution* 14:90-101.
- Allard, R. W. and P. L. Workman. Population studies in predominantly self-pollinated species. IV. Seasonal fluctuations in estimated values of genetic parameters in lima bean populations. *Evolution* (in press).
- Haldane, J. B. S. 1956. The estimation of viabilities. *Jour. Genet.* 54:294-296.
- Harlan, J. R. 1956. Distribution and utilization of natural variability in cultivated plants. *Brookhaven Symp. Biol.* 9:191-208.
- Harlan, H. V. and M. L. Martini. 1929. A composite hybrid mixture. *Jour. Amer. Soc. Agron.* 21:487-490.
- Harland, S. C. 1943. The selection experiment with Peruvian Tanguls cotton. *Bull. Inst. Cotton Genet. Lima* 1, p. 98.
- Hayman, B. I. 1953. Mixed selfing and random mating when homozygotes are at a disadvantage. *Heredity* 7:185-192.
- Hutchinson, J. B. 1958. Genetics and the improvement of tropical plants. Cambridge Univ. Press.
- Jain, S. K. and R. W. Allard. 1960. Population studies in predominantly self-pollinated species. I. Evidence for heterozygote advantage in a closed population of barley. *Proc. Nat. Acad. Sci.* 46:1373-1377.
- Jensen, N. F. 1962. A world germ plasm bank for cereals. *Crop Sci.* 2:361-363.
- Lewontin, R. C. 1958. A general method for investigating the equilibrium of gene frequency in a population. *Genetics* 43:419-434.
- Lewontin, R. C. and M. J. D. White. 1960. Interaction between inversion polymorphisms in two chromosome pairs in the grasshopper, Moraba scurra. *Evolution* 14:116-129.
- Li, C. C. 1955. The stability of an equilibrium and the average fitness of a population. *Amer. Nat.* 87:257-261.
- Moran, P. A. P. 1963. Balanced polymorphisms with unlinked loci. *Aust. Journ. Biol. Sci.* 16:1-5.
- Simmonds, N. W. 1962. Variability in crop plants, its use and conservation. *Biol. Rev.* 37:422-465.

- Suneson, C. A. 1956. An evolutionary plant breeding method. Agron. Jour. 48:188-191.
- Suneson, C. A. and G. A. Wiebe. 1962. A "Paul Bunyan" plant breeding enterprise with barley. Crop Sci. 2:347-348.
- Wright, S. 1942. Statistical genetics and evolution. Bull. Amer. Math. Soc. 48:223-246.
- Wright, S. 1949. Adaptation and selection. In Genetics, Paleontology and Selection, Ed., G. L. Jepsen, 365-389. Princeton Univ. Press.

APPLICATION OF GENETIC RECOMBINATION IN RESEARCH PROJECTS

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The Phenomenon

My topic today is a direct result of a phenomenon that is the stock in trade of animal breeders--that is sex. At a conference on evolution several years ago a number of biologists examined carefully the question--is sex really necessary? These men conceded that if sex was not absolutely essential, at least it was a matter of great convenience!! From an evolutionary standpoint, sexual reproduction is a key mechanism in the maintenance of genetic variability through recombination. Recombination is a function of three processes namely, crossing over between homologues, random segregation of chromatids, and finally the chance combination of gametes. The variety of recombinants produced by heterozygous parents are subjected continually to the competitive elements of selection. We are frequently reminded that the analytical methods of genetics center around recombination. Carson (1957) points out that a definition for a gene that is satisfactory for an evolutionist, is a hereditary entity that acts as a unit of recombination.

A useful illustration of the creative aspects of recombination in building up gene complexes that remain together is the selection experiment of Mather and Harrison (1948). Chaeta number showed a gradual increase to an average of more than 20 over the course of 20 generations. The change was too gradual to be attributed to recombination of whole chromosomes. Progress was postulated to be the result of breaking up repulsion linkages, with the gradual accumulation of favorable genes that increased chaeta number. Recombination disrupted the balance of the population genome so that selection for chaeta number resulted in a sharp decrease in fertility. Selection pressure was discontinued and all the progress made in 20 generations was lost during four generations of relaxed selection. Subsequently, fertility traits recovered, selection was resumed and the previous selected level for chaeta number was regained in only four generations. Coupling linkages built up over 20 generations apparently persisted in the population during the reorganization of the genotype concerned with fertility and general fitness. Thus the rate and immediate limit of selection progress is not determined by genetic diversity alone but by their organization into linked combinations. A short term experiment will more likely assess the properties of existing gene combinations rather than those of the constituent genes. Changing the expression of a trait depends primarily upon altering gene combinations. This is not to overlook the variability accumulated from recurrent mutation but its immediate importance to the breeder is probably inconsequential.

The purpose of this paper will be to review a few essential features from a number of studies of recombination and relate these to some key issues in animal breeding.

Recombination Examined

Dobzhansky and his students have contributed immensely to our understanding of recombination. In the 1940's they showed that *Drosophila* had evolved a system of chromosomal inversions as a means of maintaining gene combinations important to high population fitness. They found that populations usually contained two or more inversion types for the same chromosome pair because the populations had a higher fitness when two types were present; in other words the inversion heterozygotes exhibited heterosis. In experimental populations inversion types were introduced in equal frequencies. An equilibrium developed in which the heterozygote again was the predominant class. Both inversion types, no matter how unfit they might be when homozygous, were usually perpetuated. When a genome from another geographic region was introduced, the homozygous inversion types were more frequent than heterozygotes during the first few generations because the genotypes from two different regions were not "coadapted." However, within a short time, the genotypes usually were realigned by recombination and the inversion heterozygotes again became the most frequent class (Dobzhansky, 1950).

Wallace and coworkers (1953) showed dramatically that recombination is not as simple as single gene substitutions. When a chromosome or segment thereof was replaced, it led to a realignment of a large fraction of the population genotype. Coadaptation of the population's genetic structure was apparently highly dependent upon the development of favorable epistatic gene combinations. After analyzing the problem more extensively, Dobzhansky's group has published an exciting series of papers on the release of genetic variability through recombination (1958).

The work of Dobzhansky and others indicates that populations of cross fertilizing species carry a great deal of variability. A substantial number of *Drosophila* chromosomes are either lethal or sublethal when homozygous (Spassky *et al.*, 1958). There are less chromosomes in *Drosophila* but I suspect we have no easy way of assessing the relative amounts of "concealed" variability they possess in comparison with other species. The studies of Dobzhansky's group referred to here involved the analysis of variation in viability contributed by samples of the second chromosome of three species of *Drosophila*. Only chromosomes that were in the normal or subvital range were chosen for analysis. Ten chromosomes from each of two locations were evaluated for each species. Results for each species are based on counting 190,000 flies.

A wide range in viability was found among the recombinants, derived from crossing stocks possessing different chromosomes from the same location. The variation produced by crossing stocks with chromosomes from two different locations was not significantly greater. It was possible to generate from 24-43 percent of the variance in viability typical of the wild population by one generation of recombination, using only a restricted sample from that population. Many of the recombinants were lower in viability than the homozygous parent but a significant number were substantially more viable. The variance and mean viabilities did not form any special pattern. It was pointed out that a combination of chromosomes A and B might release far more variation than either

chromosome would when combined with some third chromosome C, suggesting that the viability of recombinants is the "outcome of epistatic interactions...rather than a simple additive product..." (Spassky et al., 1958). A study by Cannon (1963), a student of Carson's, confirms the findings of Spassky et al.

The work of Robertson (1955) shows how the apparent nature of gene action is influenced by the specific genetic background. When substituting individual chromosomes into a homozygous chromosome background, some substitutions were neutral, a few caused reductions in body size and the majority increased size. A diminishing returns effect was noted. Adding one chromosome generally caused a change that might be described as overdominance; a second addition behaved like dominance; a third addition like partial dominance, and the fourth in the additive range. These studies warrant critical appraisal by animal breeders in the absence of any data of our own. One cannot help being impressed jointly with the drive expressed by populations for the maintenance of heterozygosity and the conditional nature of gene action depending upon the specific genetic background of a population.

We are indebted to Anderson (1939) for his work that focuses attention on recombination. Apparently his papers have been read by some plant breeders but are almost as undiscovered by animal breeders as Mendel's work was at one time. Anderson illustrated clearly the severe restriction to free recombination imposed by linkage. Thus only a small fraction of the potential recombinants are generated in an F_2 population. The implications of this situation for both plant and animal breeding needs further critical analysis in selection experiments. Some theoretical aspects of Anderson's analysis indicate the extreme limitations on improvement inherent in programs that combine selection with maximum rates of inbreeding. He illustrated that a relatively long period of recombination is beneficial for extrating useful genotypes. He suggested also that it might be important to select and intermate a variety of recombinants from various segments of the "recombination spindle" in seeking a particular selection objective. This was illustrated with a small breeding experiment in Nicotiana. This study shows what a conservative (in fact, futile) breeding method backcrossing is if the desired objective involves recombining genes for the sharply contrasting expression of two traits. I know of no further analysis of this approach with agricultural species until the ones made by Kemp (Lethbridge, Alberta) with tomatoes and melons.

Some of our conventional concepts are shaken by the results Suneson (1956) has obtained with composite populations of barley. Various composites were established originally from the possible crosses of from 9 to 31 varieties. The material included in the total program was drawn from both California adapted varieties and stocks from the world collection. Male sterile genes were introduced in some composites. Each composite has been handled as a bulk population without selection, for as many as 35 generations. The early generations have yielded well below a standard commercial variety. There was a gradual increase in yield till several populations now exceed the standard variety. The

major force directing population change has been natural selection among diverse recombination products. Allard and Jain (1962) found that the within-family variances in one of Suneson's composites still exceeded the parental average after 19 generations of selfing in the composite. They postulated strong selection for heterozygosity. It was also pointed out that the occasional outcross could lead to a new burst of segregation (Allard's paper at this meeting gives a detailed treatment of this problem). Suneson (1956) indicates the low cost involved in carrying these populations as a broad gene source, while they are continually subjected to natural selection in the region of intended use. He proposed three levels of work on plant improvement: (a) a broadly based series of composites continually subjected to natural selection as a nucleus or foundation program, (b) periodic hybridization of promising materials with intervening generations of natural selection, and (c) conventional selection, testing, and variety release.

Broadening the genetic base for effective plant improvement is increasingly frequent. In one of the earlier studies of this kind, Griffing and Lindstrom (1954) obtained a substantial increase in hybrid corn yields by incorporating Brazilian germ plasm (completely unsuitable by itself) into adapted inbred lines.

Lonnquist and Gardner of Nebraska have re-evaluated the broader use of recombination in relation to effective selection for corn yield (Lonnquist, 1961). The persistent response under recurrent selection was attributed in part to the generation of recombination (intercrossing among selected parents) during each cycle. Their program has included a new study of mass selection which has shown a continual and substantial yield increase. Population changes per year either equal or exceed those obtained by recurrent selection at a fraction of the input of resources. The procedure is simple and direct. A further key issue for animal breeders to consider is that the starting point in most plant breeding programs is hybridization, and the process is repeated as frequently as is deemed useful to maintain variability for effective selection.

Wright (1922) proposed a general system of genetic improvement which I have chosen to call "cyclic recombination" (illustrated in figure 1). This is similar to what plant breeders have actually done for years. There are data from experimental animal populations that indicate its validity. Falconer and King (1953) found a renewed response to selection for body size using a mouse population based on crossing the plateaued large lines of MacArthur and Goodale. This finding is supported also by the extensive results of Robertson and Reeve with *Drosophila* (Robertson, 1955). In the mouse experiment it was concluded that plateauing occurred because of a reduction in genetic variance. However, in the fly studies there was no appreciable change in heritability estimates even after many generations of intense selection for large body size. There was no doubt about either the plateau or the renewed response after crossing in these experiments. Thus heritability estimates cannot serve as the sole guide to assess selection response. However, the key finding here is that selection limits were extended in the desired direction after crossing two genetically diverse, plateaued lines, as a result of selection among the recombinants produced.

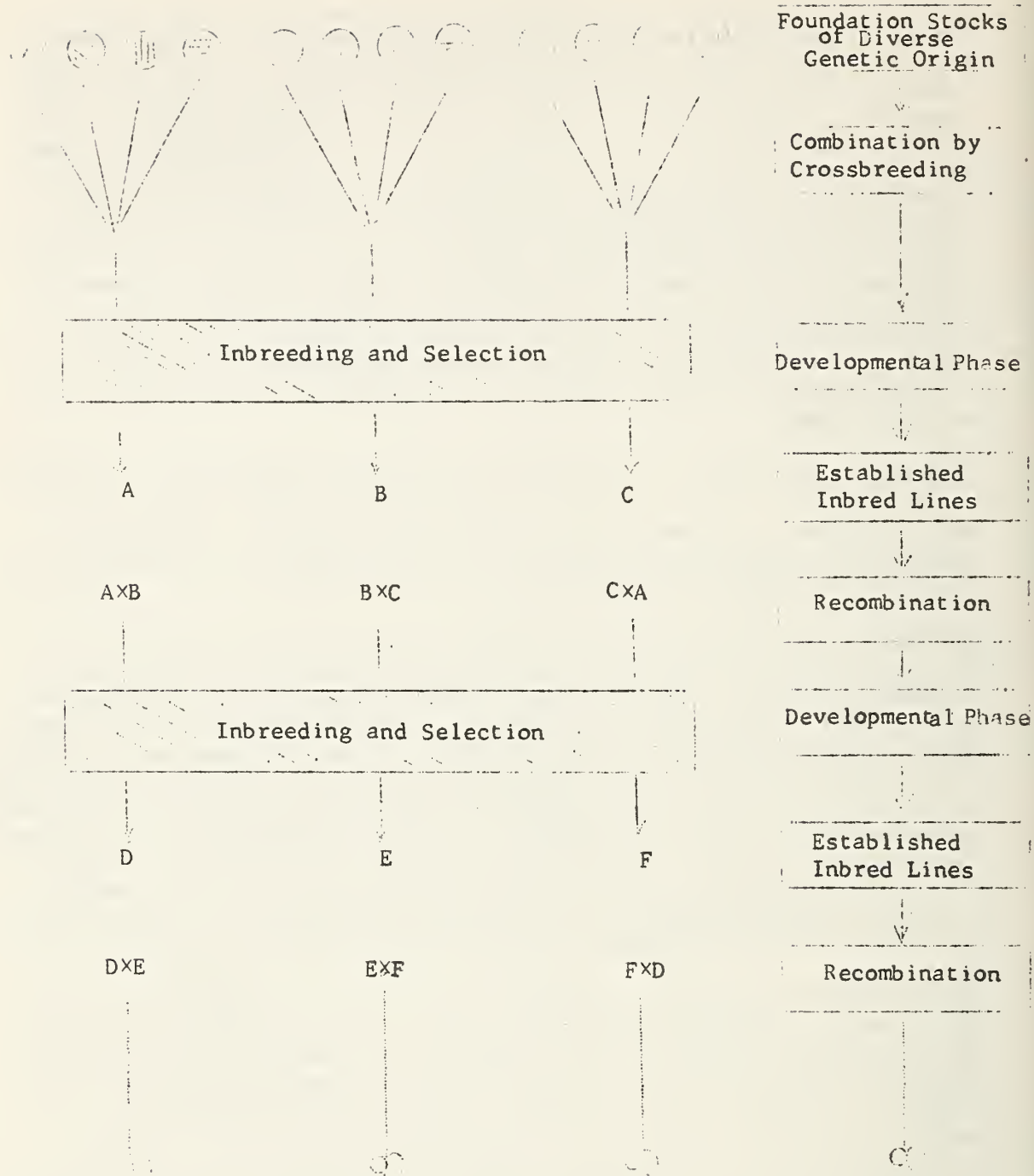


Figure 1.--A general system of animal improvement by "cyclic recombination" (after Wright, 1922)

Recombination and Animal Breeding

We have no data from farm mammals bearing on recombination which is comparable to that with laboratory animals or plants. Combs (appearing on this program) has reviewed and analyzed the meager data that do exist. The results are interesting but do not provide an adequate assessment of the situation. This work requires the straight forward effort of crossing two or more contrasting breeds in substantial numbers, gathering comparative data on the parent lines and the crossbred foundation for a number of generations. It is curious that despite the amount of crossbreeding and selection work that has been done, only two or three small studies with sheep and dairy cattle provide data. Studies just starting with swine and beef cattle promise to shed further light on recombination.

The limited range of study to which recombination has been relegated in animal breeding research suggests that we have suffered from a plateau effect. In this case it is a plateaued population of ideas. Most professional animal breeders have only a hazy notion about the amount and kind of variability released by recombination when crossbred stocks are mated inter se. Few breeders have had the opportunity (yes, the privilege) of working with the early segregating generations after breed crosses. The general concepts that apparently prevail among us are erroneously transposed from reported F_2 distributions in plants. I have heard animal breeders talk about the "degeneration" or "wild" segregation that occurs if one uses crossbred sires on crossbred females. These concepts are less prevalent today but the uncertainty persists. First of all, the rate of inbreeding is much lower in our animal populations. We have an opportunity to practice selection among the recombinants produced as a means of either maintaining or advancing population performance relative to the average of the first cross. Furthermore, the residual heterosis for fertility and survival expressed may be sufficient to augment selection differentials for a number of generations (Dickinson and Touchberry, 1961). I have worked closely with nearly a dozen populations of swine based on foundations of from two to twelve breeds (both experiment station and industry). Aside from variation in color and conformation, the phenotypic variation in traits of real economic value is similar to that of populations derived from a single breed. General observations of new breeds of cattle would indicate the same situation.

One of the important issues is what is the nature and relative rate of selection response in a population founded on a cross of two or more breeds as compared to similar selection in the parent breeds? We have no firm evidence on this question yet. (We contemplate such a study with cattle at Nebraska.) Work of this kind can tell us in direct terms what we can expect from migration in general and recombination in particular. The vast majority of breeding research has been conducted with existing breeds. Probably crossbred foundations did not seem to be the first question for evaluation. Obviously there has been both conservatism among researchers, particularly beef cattle breeders, and substantial public pressure to use the more popular breeds just as they are. However, if we really address ourselves

objectively to the important issue of maximizing selection progress, crossbred foundations are a necessary area of study. One assumption is that populations from a cross might have higher genetic variances for key economic traits. Heritability estimates from swine populations do not support this hypothesis (El-Issawi and Rempel, 1961). A critical selection experiment may be required to assess the situation if we consider the high heritabilities obtained by Robertson (1955) in his plateaued populations. That is, the final answer is the realized heritability, not the prediction.

It is now obvious that new breeds can be developed in a working lifetime from crossbred foundations. Many breeds of swine and a few breeds of cattle were developed in North America since 1920. Apparently Russia is using this approach more extensively than the United States, by importing animals from throughout the world and crossing with their local stocks. A major question is by which procedures can we maximize the rate of improvement of productive efficiency. Neither species nor breeds are a justifiable research restriction. Our fundamental obligation is to people.

Gene Pools

Recently, several workers have given important papers regarding untapped germ plasm resources. Phillips (1961) emphasized the material from Asia, Africa, and Europe. We have worked with an extremely small fraction of the world's store of variability. We continue to work with cattle breeds that have been in existence for over 100 years. No doubt the British breeds are prevalent here because of: (a) tradition tracing back to the ancestral home of early pioneers, (b) colonial control of commerce by England, and (c) aggressive export policy and promotion by the British on into the 19th and 20th centuries. Because of the mode of development, it may be quite accidental if the British breeds are better adapted to United States ranges than any other cattle in existence. We talk about importing exotic germ plasm, yet some of the germ plasm most "foreign" to cattle breeders has been with us for many years. We have not determined what might be evolved from crosses of the British breeds. Milk production is a major limiting factor in beef production. We can modify this by the dismal fraction of one percent (or less) per year by within-breed selection, or we could introduce genes for milk production from a dairy breed. Miles City has started work in this direction; I hope it is carried through the next logical two or three phases to answer some of the pertinent questions.

Less mental barriers were involved in using new gene sources to improve adaptation to regional environments. We displaced the Longhorn because they were not adapted to more intensive beef production (I do wonder if they possess some useful genes for general adaptation). Zebu type cattle have contributed extensively to efficiency of beef production in the United States through both commercial crossing and breed building. Canada has evaluated the infusion of bison genes into cattle to increase cold tolerance. The Manyberries, Alberta herd now contains about 15% bison genes and the appearance of the animals confirms their presence.

The growth rate, carcass merit and fertility of the Cattalo population is now similar to conventional cattle. The Manyberries Station has also evaluated the Brahman-British cross cow over the past 8-10 years. These cows have consistently produced the heaviest calves and had the least winter weight loss. Their total program points critically at the obvious fact that even in northern climates, heat tolerance is important for a large fraction of the year. Now would it be possible to increase the range of climatic tolerance of cattle by selecting within Brahman-Highland or Brahman-Bison foundations? Intuitively we might say---no---but where's the evidence?

Other workers have suggested that we broaden our genetic base for livestock improvement. Dr. R. T. Clark of this group has suggested repeatedly that we return to the old European draft cattle to obtain genes for size and muscling. Henry A. Wallace (1961) admonished animal breeders to begin a more vigorous search, not for unique animals per se, but unique blocks of genes. Wallace suggested that detecting useful gene complexes may require extensive hybridization and selection in the tradition of the Harlans and Suneson. The responsibility of animal breeders is not only finding existing unique, useful gene complexes but devising procedures for building these complexes through recombination and selection.

My views on gene pools are presented in detail in another paper (Sumption, 1963). I think that gene pools should be formed by animal breeders to assess the feasibility of this approach for maintaining useful genes for future breeding programs. I am not convinced that we can rely on the world's livestock industry to perform this function unassisted. Our animal germ plasm is a basic international resource. We have never really treated the situation this way despite the plant germ plasm program which has been active for over 40 years.

The Nebraska Station has two gene pools of swine at the present time, namely Lines X and Y (figures 2 and 3). A third pool (Line Z, figure 4) will be formed in the future. We will use part of the Nebraska stock to appraise effectiveness of selection for reproductive performance in addition to a general appraisal of the variability in these populations.

As I see it gene pools might be used at several levels in animal breeding programs:

A. Research and Maintenance of Basic Resources

1. Broad gene pools--serving as general gene sources, several in number, composed of many different breeds, maintained at several locations in large herds, random selected, freely recombining populations. The objective would be to minimize the cost of maintaining a maximum variety of genetic material.

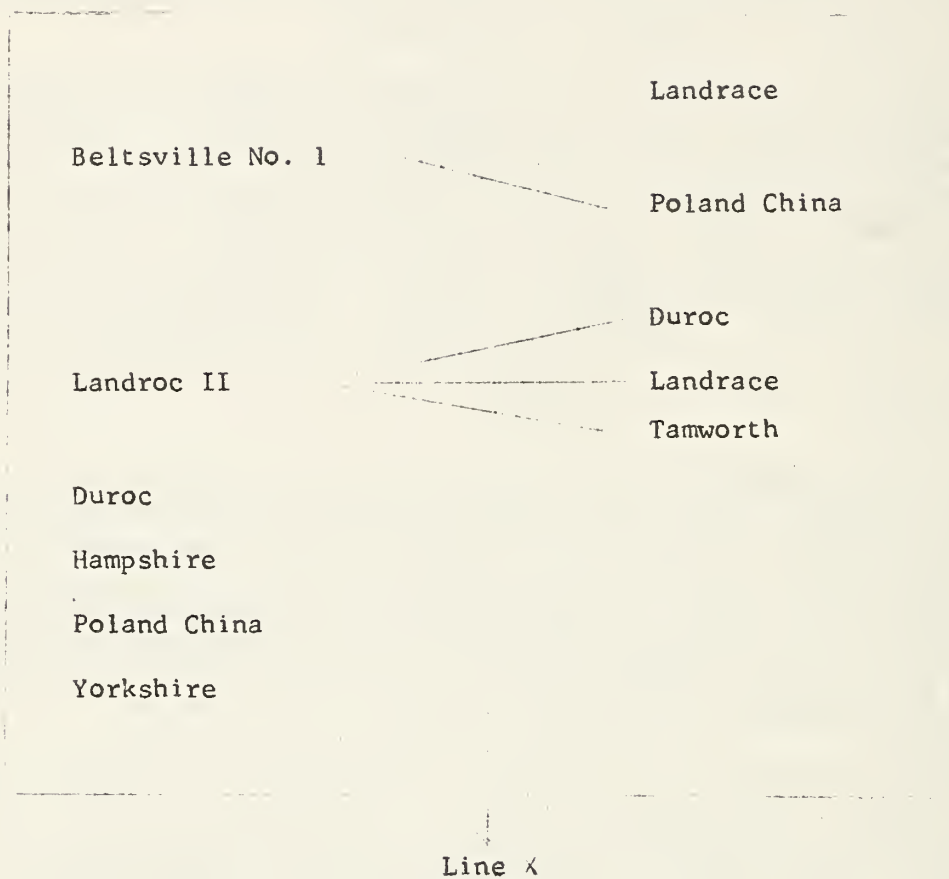


Figure 2.--North Platte Station gene pool

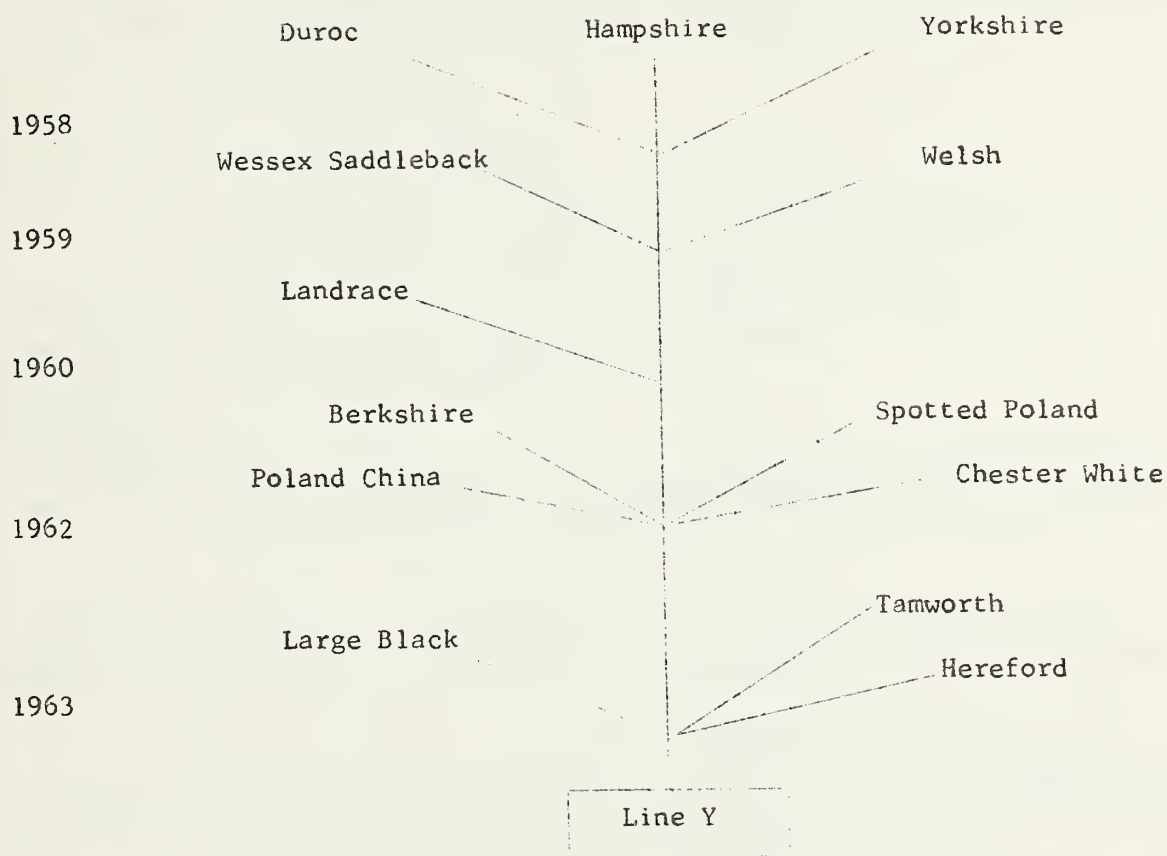


Figure 3.--University of Nebraska gene pool of old breeds

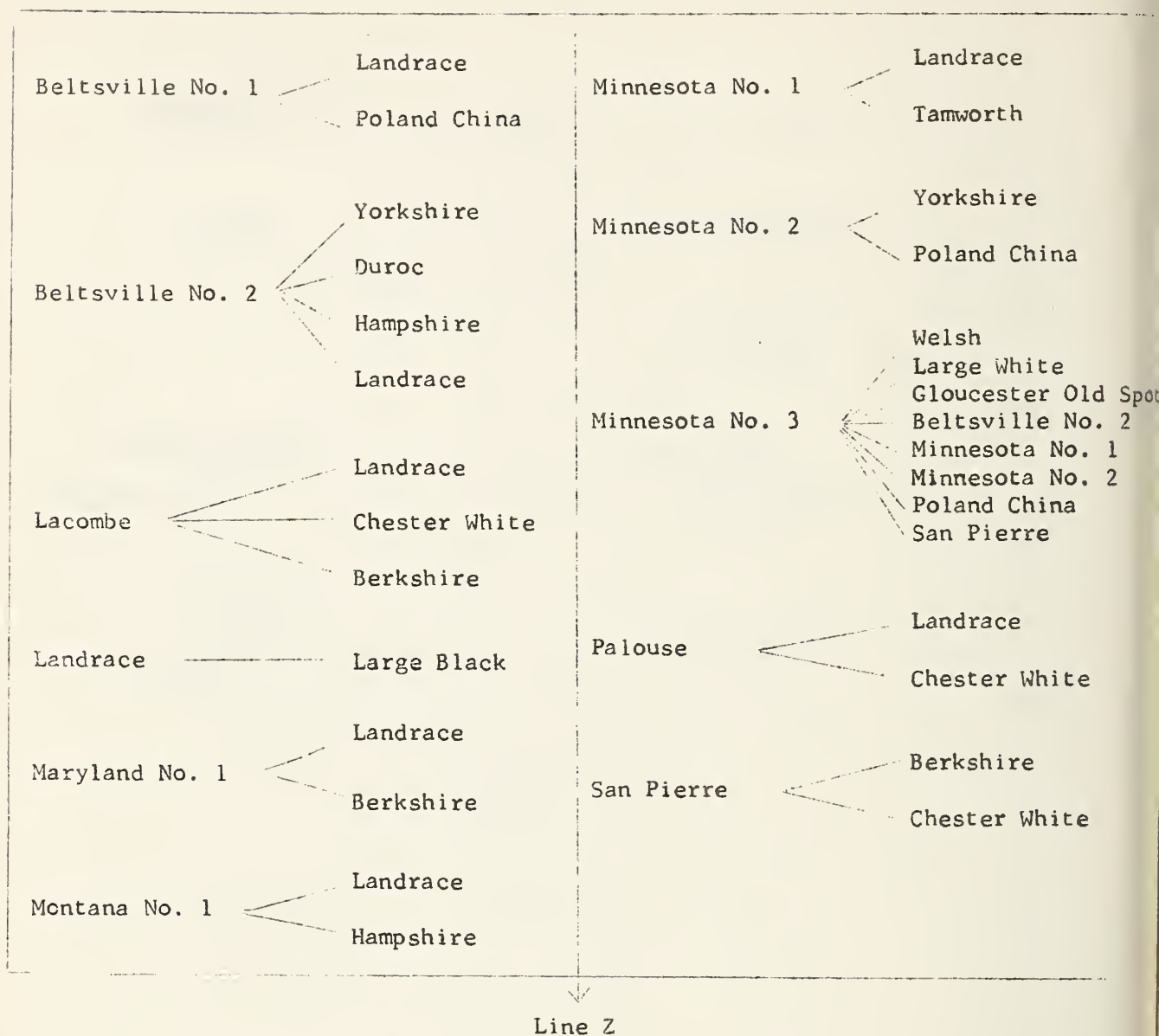


Figure 4.--University of Nebraska gene pool of new breeds

2. Gene pools based on two or three breeds--directed toward pooling genes from breeds that may complement one another in an interbreeding population. The objectives would be more specific (than in A1) in attempting to determine effective means of maximizing the rate of improvement for an aggregate of economic traits. The number of pools so developed would depend on the number of problems perceived and the number of approaches to these problems deemed worthy of research.

B. Industrial Development

1. Isolates from gene pools--used to improve existing breeds or to build new breeds. This work would involve "tailoring" useful genetic material to satisfy a specific set of production and marketing conditions, not properly research effort. This approach has already been utilized by several private breeding organizations. It is reasonable to expect this work to increase.
2. Breed maintenance--not far different from present procedures for retaining breed identity, promoting improvement, and use of existing breeds. Hopefully the effort will be more constructive and self critical.

It should be clear that we really know very little about the genetics of the animals with which we work. There are several things we might do to prepare ourselves to understand recombination:

1. Identify genes to use for detailed analysis of gene complexes, dropping the fear of being called "gene chasers." We need markers such as coat color, blood types, serum protein patterns as an aid to our work with quantitative traits.
2. Build populations composed of two or more breeds with the intent of analyzing the variability in advanced generations after crossing.
3. Investigate phenomena about which we may be sure we know facts that are not necessarily so. I am thinking of some of the supposed genetic antagonisms, such as muscle development and milk production, wool yield and muscle growth, wool fiber length and diameter, or average daily gain and muscle development. These projects could involve estimating genetic correlations in several parent breeds compared with segregating generations from a crossbred foundation under random selection. Genetic correlations should also be examined where all populations are subjected to "maximum" selection for two traits that are unfavorably correlated. Several different methods of multiple trait selection should be evaluated relative to the feasibility of altering genetic correlations

4. Investigate optimum mating systems in relation to recombination potential. Winters (1955) recommended a "slow, deliberate segregating stage," implying a relatively low rate of inbreeding. The results of Tantawy (1956) indicate the restrictions imposed upon total selection response (thus on recombination) by rapid inbreeding. Rapid inbreeding will always be used to progeny test for simple inherited defects in farm animals. Beyond this point I believe that selection will be the radical tool for population improvement, and inbreeding will be only a consequence of practicing selection within closed populations. Development of highly inbred lines does not provide adequately for continual improvement. Fertility levels and population size in farm animals are inadequate to allow an effective combination of rapid inbreeding and selection. It is likely that we have accepted the inbred-hybrid system of commercial plant breeding as our objective without adequate transposition to the biological limitations of our species. The theoretical, biological, and practical considerations appear to weigh against any major use of inbreeding. Further evidence may be necessary to place this total problem in perspective, hopefully most of the needed data from new studies can be obtained without obligating extensive resources from large animal breeding research.

Conclusions

Recombination is the powerful phenomenon underlying effective selection. To fully exploit selection we must gain a better understanding of recombination in the species with which we work. It is possible that we may be able to establish populations with the average merit similar to favorable transgressive segregates, as has been accomplished with other species (Smith, 1952).

Literature Cited

- Allard, R. and S. K. Jain. 1962. Population studies in predominantly self-pollinated species. II. Analysis of quantitative genetic changes in a bulk-hybrid population of barley. *Evolution* 16:90-101.
- Anderson, Edgar. 1939. Recombination in species crosses. *Genetics* 24:668-698.
- Cannon, G. B. 1963. The effects of heterozygosity and recombination on the relative fitness of experimental populations of Drosophila melanogaster. *Genetics* 48:919-942.
- Carson, H. L. 1957. The species as a field for gene recombination. The Species Problem. A.A.A.S. Publ. No. 50:23-38.
- Dickinson, F. N. and R. W. Touchberry. 1961. Livability of purebred vs. crossbred dairy cattle. *J. Dairy Sci.* 44:879-887.

- Dobzhansky, T. 1950. Genetics of natural populations. XIX. Origin of heterosis through natural selection in populations of Drosophila pseudobscura. Genetics 35:288-302.
- El-Issawi, H. F. and W. E. Rempel. 1961. Heritability of growth rate in inbred swine based on a crossbred foundation. J. Animal Sci. 20:593-596.
- Falconer, D. S. and J. W. B. King. 1953. A study of selection limits in the mouse. J. Genetics 51:561-581.
- Griffing, B. and E. W. Lindstrom. 1954. A study of the combining abilities of corn inbreds having varying proportions of CornBelt and Non-CornBelt germ plasm. Agronomy J. 46:545-552.
- Lonnquist, J. H. 1961. Progress from recurrent selection procedures for the improvement of corn populations. Nebr. Agr. Exp. Sta. Res. Bul. 197.
- Mather, K. and B. J. Harrison. 1949. The manifold effect of selection. Heredity 3:1-52; 131-162.
- Phillips, R. W. 1961. Untapped sources of animal germ plasm. Germ Plasm Resources. A.A.A.S. Publ. No. 66:43-76.
- Robertson, F. 1955. Selection response and the properties of genetic variation. Cold Spring Harbor Symp. Quant. Biol. 20:166-177.
- Smith, H. H. 1952. Fixing transgressive vigor in Nicotiana rustica. Heterosis. pp. 161-174. Iowa State Col. Press, Ames, Iowa.
- Spassky, B., N. Spassky, H. Levene and T. Dobzhansky. 1958. Release of genetic variability through recombination. Genetics 43:844-867.
- Sumption, L. J. 1963. Methods of maintaining gene pools. Proc. Canadian Soc. Ani. Prod. (in press)
- Suneson, C. A. 1956. An evolutionary plant breeding method. Agronomy J. 48:188-191.
- Tantawy, A. O. 1956. Selection for long and short wing length in Drosophila melanogaster with different systems of mating. Genetics 28:231-262.
- Wallace, B., J. C. King, C. V. Madden, B. Kaufmann and E. C. McGunnigle. 1953. An analysis of variability arising through recombination. Genetics 38:272-308.
- Wallace, H. A. 1961. Origin and utilization of germ plasm in the United States. Germ Plasm Resources. A.A.A.S. Publ. No. 66:77-90.
- Winters, L. M. 1955. Building breeds as a problem in population genetics. Breeding Beef Cattle for Unfavorable Environments. pp. 127-132. University of Texas Press, Austin, Texas.
- Wright, S. 1922. The effects of inbreeding and crossbreeding in guinea pigs. III. Crosses between highly inbred families. U.S.D.A.Bul.1121.

RECOMBINATION OF QUANTITATIVE TRAITS AND POSSIBLE USES
IN BEEF CATTLE IMPROVEMENT

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Commenting on the establishing of new races from crossbred foundations, Darwin in Origin of Species observed, "The offspring from the first cross between two pure breeds is tolerably and sometimes (as I have found with pigeons) quite uniform in character, and everything seems simple enough; but when these mongrels are crossed one with another for several generations, hardly two of them are alike, and then the difficulty of the task becomes manifest."

Heterozygosity and Variability. Wagnon et al. (1960) state the widely held view that close-breeding is a "powerful tool" in establishing uniformity and that outbreeding decreases the general uniformity of the herd. Basic to Lerner's (1954) thesis of genetic homeostasis, however, was the tenet that heterozygous populations are less variable in quantitative traits than are those more homozygous. Recognizing his admitted selectivity in presenting evidence on this point, it still must be conceded that the scientific literature more often supports than contradicts this view. It should also be recognized that livestock F_1 's are not classic F_1 's when quantitative traits are considered and in most cases are segregating populations in one degree or another. No review will be made of evidence cited by Lerner. Examples not cited by him will be drawn upon.

England (1952), in an analysis of crossbreeding in swine at the Minnesota station, presented rather substantial evidence supporting the view that hybrids are less variable in quantitative traits. Not only were the coefficients of variability lower for the crossbreds than for their inbred parents, but the standard deviations were lower for all crossbred groups in two of the three traits even though all crossbred means were higher than those of the inbred groups. Fausch (1953), analyzing some of the same data, concluded that this relationship generally prevailed between levels of inbreeding within the inbred lines studied. Hugh (1955) reported that this relationship also generally was found within inbred Poland-China lines.

Baker and Black (1950) published performance data on Brahman-Angus and Africander-Angus crossbred cattle. In weight comparisons made from birth to six years, the Brahman-Angus F_1 showed very similar variability to the parent Angus herd in birth and weaning weights and was more variable than the Angus only at four years of age. The Africander-Angus F_1 was slightly less variable than the Angus. The Brahman-Angus F_2 showed slightly more variability than either the F_1 or Angus herds. The Africander-Angus F_2 showed less variability in birth weight but more variability in weaning weight than either the F_1 or Angus herds. The absence of data on the Brahman and Africander parents makes comparative

interpretation difficult, however. When comparisons were made of 3/4 Angus, 1/4 Brahman calves at birth and weaning, those out of Angus dams were twice as variable at birth as those out of F_1 dams. At weaning, those out of Angus dams were 50% more variable than those out of F_1 dams.

Cole and Johansson (1948) reported on the crossbreeding of Jersey and Holstein dairy cattle with Angus beef cattle. The coefficients of variability of the Angus-Holstein cross for fat corrected milk (FCM) and butterfat percentage were calculated. Startling increases in variability in FCM were reported in the hybrid generations. Variability in butterfat percentage, on the other hand, declined slightly in the F_1 and F_2 . Small numbers further complicate interpretation.

An analysis of 100 wool fibers from each of seven body locations in six Rambouillet, two Hampshire, 20 F_1 , and 13 F_2 samples (Burns, 1933, and unpublished original data) showed C.V. values of 21.42, 19.03, 21.04, and 23.78, respectively. While the numbers are small and the hybrids are not less variable than the purebred parents, the small differences do not support any expectation of greatly increased within-fleece variation in the hybrid generations.

Fohrman *et al.* (1954) reported variability in milk traits in purebred and crossbred dairy cattle. Fifty-five purebred cows had a C.V. of 35.4 for milk production as compared to 12.9 for 55 two-breed crosses and 17.5 for 58 three-breed crosses. The C.V. for the purebreds corrected to a within-breed basis was 24.0, nearly twice that for the F_1 cows. Similar relationships in C.V. values for fat test and butterfat production were also reported.

Ritzman (1923) published a body of data on body measurements of Southdown and Rambouillet sheep and of their subsequent filial generations that lends itself to analysis for variability and recombination. Fifty ewes of each parent breed, 36 F_1 and 41 F_2 females were studied. It will be noted (table 1) that of 14 body measurements, in the F_1 the C.V. values of 10 were smaller than those for either parent, two were intermediate and two were larger. F_2 values were generally larger than those for the F_1 but were generally intermediate to the parental C.V. values. The variation of ratios of various body traits showed a similar relationship.

Davenport and Ritzman (1926) reported variability studies of certain wool traits in purebred and hybrid populations. Variability in wool fiber diameter in three F_1 groups was intermediate to that of the parent breeds. The Southdown-Rambouillet F_2 was less variable than the F_1 , while the Hampshire-Rambouillet F_2 was more variable than the F_1 and either parent breed. The Southdown-Rambouillet F_3 was less variable than any previous generation, while the Hampshire-Rambouillet F_3 was more variable than the F_1 but less variable than the F_2 and the most variable parent. The variability in fleece weights declined with one minor exception through the filial generations.

Table 1.--Variability in body measurements

	50		50		36 F ₁		41 F ₂		Coefficient of variability			
	Southdown		Rambouillet		Mean		Mean					
	Mean	mm.	Mean	mm.	Mean	mm.	Mean	mm.	50 Sn.	50 R.	36 F ₁	41 F ₂
Vertical Dimensions:												
Height	581.00		675.00		605.83		626.83		3.33	4.93	2.84	4.73
Chest depth	304.70		314.00		305.70		314.63		4.08	5.33	2.96	4.71
Foreleg length	356.70		422.00		391.25		403.17		4.65	5.30	4.16	4.17
Hind leg length	417.50		478.00		444.86		453.61		5.55	5.00	3.25	4.63
Longitudinal Dimensions:												
Head length	184.60		210.70		187.50		197.93		3.54	6.00	4.72	4.53
Neck length	286.00		298.80		295.97		316.59		6.98	7.20	7.20	4.63
Trunk length	594.00		633.00		611.50		606.00		4.16	4.06	3.90	4.93
Croup length	159.20		158.50		149.16		164.39		7.49	9.12	7.43	8.47
Transverse Dimensions:												
Head width	124.30		124.30		126.91		136.10		4.19	5.96	4.97	5.29
Chest width	258.30		202.00		205.00		224.51		6.60	6.87	6.17	9.52
Loin width	159.60		129.50		132.94		148.78		8.39	9.04	7.64	11.69
Circumferences:												
Chest	964.50		817.20		820.00		871.59		5.83	6.65	5.01	6.07
Hind leg	455.50		372.91		408.20		414.88		7.55	6.36	6.97	4.41
Weight	141.6		130.0		114.03		120.22		10.77	8.12	12.64	6.09

From: Ritzman (1923)

After studying crosses of Nicotiana, East (1916) concluded that F_1 populations were as uniform as the parents but the F_2 was nearly three times more variable than the F_1 . The variability of F_3 families was reported to be "invariably" smaller than that of F_2 families.

Yapp (1925) reported C.V. values in milk traits for Holstein and Guernsey purebreds, their F_1 and the subsequent F_2 . In percent fat content, the F_1 was clearly less variable than either parent breed while the F_2 was intermediate. In percent protein, the F_1 was slightly less variable than the more variable parent, the F_2 slightly more variable than the less variable parent breed. In percent lactose, the F_1 was intermediate in variability between the two parent breeds and the F_2 more variable than the more variable parent. In percent ash, both the F_1 and the F_2 were intermediate between the parent breeds with the F_1 approaching the less variable parent. Fourteen F_1 and 19 F_2 cows were included in the summary. The project was continued with approximately twice as many crossbred females eventually being included. A final summary has not been made.

The evidence appears to support the view that the most heterozygous population, the F_1 , is generally less variable in single traits than are the parental populations. This was especially confirmed where larger numbers of animals were involved. Even in smaller experiments, the F_1 rarely exceeded the more variable parent breed. The F_2 was less predictable but was more frequently intermediate or more variable than either parent but in no case was an expectation of greatly increased variation in crossbred populations fulfilled. This may indicate that even our oldest breeds of livestock are not as divergent genetically as is frequently supposed.

Recombination of Quantitative Traits. Yapp (1925) concluded from his summary of Holstein-Guernsey F_2 data that milk traits were conditioned by several genes and that no indications of segregation were evident. Coefficients of variation of individual traits would appear to support this conclusion, though the necessity of examining more than one trait simultaneously was not recognized. Although the originator of this project, T. J. Bowlker, Framingham, Massachusetts, hoped to recombine the high milk volume of the Holstein with the high fat of the Guernsey, Illinois researchers who continued the project disclaimed such an objective (Gaines, et al., 1925).

Anderson (1939) reported observations of the recombination of pairs of traits in crosses of Nicotiana alata and N. langsdorffii in a paper which Winters (in Rhoad, 1955) terms "a classic." When species with contrasting traits were crossed, the F_1 tended to be intermediate. F_2 traits when plotted graphically in pairs did not recombine randomly, but recombined along a restricted elliptical "spindle" which ran diagonally between the parental populations.

Anderson attributed the restricted recombination to gametic elimination, zygotic elimination, pleiotropy, and linkage. The ratio of observed recombinations to the total possible was calculated to be $(a/t)^{n-1}$

where "a" was the narrow radius of the F_2 spindle at the center, "t" the diagonal radius of the square graph, and 2^n the number of traits being plotted (figure 1). Estimating the average recombination of any two traits in his study to be 1/4 of the total possible, the expected recombination for three traits would be 1/16, for four traits 1/64, etc. The correlation coefficients between traits increased from small plus or minus values in the F_1 to high positive values in the F_2 .

Although observed recombination of parental traits was only a fraction of the total possible, Anderson proposed systems of mating designed to promote further segregation and recombination. It was calculated that to recombine contrasting parental traits, the mating of F_2 opposites was as efficient as selfing the "most desirable" F_2 individuals and four times more efficient than crossing "most desirable" individuals as would be necessary in livestock breeding. Furthermore, the mating of parent-like opposites would minimize the risk of cutting off valuable parental genes, thus maximizing the possibilities of ultimate complete recombination. The mating of opposites was also calculated to be more efficient than back-crossing to either parent. When the desired trait comes from both parents, it was proposed that recombination be promoted by supplemental selection for contrasting "marker" traits that are typical of the parental stocks.

Critical experimental data on Anderson's proposals are lacking. At the Lethbridge, Alberta, Experiment Station, however, Kemp (1961) has been successful in recombining the early maturity of a tomato variety having small fruit with the large fruit size of a variety which was late maturing. From an F_2 spindle of 4000 plants, 10 were selected from the area of the spindle which best recombined early maturity with large fruit size. These were selfed. In F_6 , one line was produced which had a fruit size as large as the "large" parent and was slightly earlier in maturity than the "early" parent.

Other plant breeders have reported successful results from recombination experiments. Suneson (1956) and Bal et al. (1959) reported the results of natural selection in California barley populations. Atlas 46, an adapted California variety, was used as the control. One bulked population consisting of 28 barley varieties crossed in all possible (378) combinations was planted each season under no selection except natural selection. At F_2 , it was about 75% as productive as Atlas 46. At F_{20} , it was equal to Atlas 46 and went on to exceed the control in succeeding generations. Two other bulked populations showed similar trends, and a fourth consisting of none adapted California varieties advanced from less than 90% of Atlas 46 in F_2 to more than 100% of the control by F_{8-12} . This latter population contained a male sterile gene which allowed continuing gene recombinations through natural crossing concurrent with natural selection.

Allard (1961) reported similar successes with lima bean crosses in California. Three inbred lines of "high", "medium", and "low" productivity were crossed in the three possible two line combinations. At F_7 or F_9 the high-medium and medium-low crosses exceeded the higher



Figure 1.--A schematic description of recombination involving crosses of population with a contrasting association of traits (after Anderson, 1939, and Kemp, 1957)

parent in production and the high-low cross approached the "high" parent. The average of the three crosses exceeded that of the three parent lines. No conscious selection had been practiced. The cross populations were also more stable in their relative production in various environments. Their superior yield was attributed to their consistency in all environments as contrasted to the great variation of certain parents from one environment to another.

The classic dog experiments of Stockard (1941) presented dramatic evidence of the recombination of single and multiple gene traits in the F_2 generations following the crossing of breeds of contrasting appearance. The experiments were started to show the relationship between endocrine function and variations in skeletal structure; but, length of upper jaw segregated independently of length of lower jaw, and other skeletal measurements independently of one another. It was concluded that a dog's size seemed not be the result of some general genetic or endocrine function but due rather to the recombination of various components of body size. Scott et al. (1959) reported some evidence of segregation of the annual and semi-annual estrous cycles of hybrid Basenji-Cocker Spaniel dogs. Numbers were too small to make a clearly cut analysis, however.

The swine gene pool projects at the University of Nebraska have been reported in detail at this symposium by Dr. L. J. Sumption.

At the Manyberries, Alberta, Range Experiment Station a cattalo (domestic cattle-bison) project is under the direction of Dr. Hobart Peters (Logan and Sylvestre, 1930; Smoliak and Peters, 1955; Peters and Newbound, 1957; Peters, 1958, 1959, 1961). Due to sterility in males carrying a high proportion of bison genes, backcrosses to domestic cattle have been made. At present, the herd carries an average of about 15% bison genes. While the project is largely of theoretical interest, a practical objective was to incorporate the winter hardiness of the bison into a cattle population. While many of the cattalo could not be distinguished from crosses of domestic breeds, others bear unmistakable bison characteristics such as coarseness of the forequarters and shaggy hair coats. These were being deliberately selected to maintain the highest possible level of bison influence.

The theoretical work of Hanson (1959a, b, c, and d) further undergirds the expectation of the breakup and recombination of parental gene blocks. He calculated that relative length of any parental chromosomal segment would decrease (greater recombination) as the number of parents in the cross, the length of the linkage block, and the number of intermating generations after crossing increased. Hanson recommended that at least four intermating cycles in maize be allowed before inbreeding was commenced.

The late Dr. L. M. Winters of the University of Minnesota has undoubtedly been the leading exponent of the use of the recombination principle in the development of new livestock lines and breeds. Winters (1954) stated that the recombination of genes had received practically no

emphasis in animal breeding circles but that, in his opinion, the regrouping of genes offered the constructive animal breeder his greatest opportunity for improvement. He also cited the development of the miniature pig to illustrate that recombination offered the opposite potential. Although Winters indicated that he mated animals with contrasting incidental marker traits to supplement selection for performance traits in the development of new breeds from crossbred foundations, swine breeds do not sufficiently contrast in performance and appearance to permit the utilization of Anderson's methods as extensively as might be envisioned in other species.

The Santa Gertrudis was developed from the genetically diverse Brahman-Shorthorn foundation (Rhoad, 1955). The Beefmaster breed was developed from a Brahman-Hereford-Shorthorn gene pool (Lasater, 1958) through the use of rather bold selection criteria. The Columbia sheep was founded on the diverse foundation of the fine-wool Rambouillet and the long wool Lincoln (Briggs, 1958). There is no evidence, however, that any attempt was made to recombine the parental traits and the breed today is intermediate in its wool characteristics. Since parent-like extremes were culled in the early generations, it appears that the full potential of recombination was not recognized by the breed founders.

There is a paucity of extensive livestock F_2 data in the scientific literature. In that reported, recombination was sometimes recorded, but the potential for livestock improvement does not appear to have been recognized. Kuhlman (1915) published pictures and descriptions of a small herd of Angus-Jersey crossbreds in England. Recombination of contrasting quantitative parental traits was inferred from the report.

MacKenzie and Marshall (1917) crossed two Australian Merino rams with Shropshire ewes. Single trait variation in the F_1 and F_2 was studied. Segregation was indicated though the observations were not reported in such a way as to permit an analysis of recombination. It was concluded, however, that the breeder would be well advised to keep his sheep in all possible purity.

Nichols (1925) classified a Border Leicester $\times$ Cheviot F_2 by head form, body conformation, and fleece type. The F_1 showed some variation, but no parental types were produced. Of 103 F_2 wether lambs, however, there were 18 typical Border Leicesters, 64 typical halfbreds (F_1), 20 of the "indefinite" class and one of Cheviot type. Of the 20 "indefinites" there were Border Leicester fleeces on Cheviot bodies, Border Leicester fleeces on halfbred bodies, Cheviot fleeces on Border Leicester bodies, Cheviot fleeces on halfbred bodies and a few halfbred fleeces on Cheviot and Border Leicester bodies. Eighty-three F_2 females showed a similar classification. Nichols concluded that halfbreds did not breed true except with careful selection. The possibility of developing a new intermediate breed was suggested but the potential of recombining desired parental traits seems not to have been recognized.

Burns (1933) reported the crossing of Hampshire and Rambouillet sheep. In an F_2 of only 13 individuals, the appearance of Rambouillet-like fleeces on Hampshire-like bodies and other evidence of recombination was reported.

Castle (1919) summarized the work of T. J. Bowlker of Framingham, Massachusetts, who had made reciprocal crosses of Holstein and Guernsey dairy cattle. It was hoped to recombine the fawn color, high fat, and rich, cream color of the Guernsey with the "more rugged" constitution, larger size, and high milk yield of the Holstein. The project was carried on by Bowlker from 1911 until his death in 1917. In 1919 it was turned over to the University of Illinois. Partial summaries were made by Gaines *et al.* (1925) and Yapp (1925 and 1931). Apparently in answer to critics, it was stated, "Creation of a new breed of dairy cattle is not the object of the experiment as is sometimes supposed." From studying single trait variation, it was concluded that little or no F_2 segregation was occurring in milk volume, butterfat percentage, percent ash, percent lactose, and percent protein. Multiple trait analyses for recombination were not made. A complete summary is now in progress.

Ritzman (1920) reported a preliminary summary of a Rambouillet-Southdown crossbreeding project at the New Hampshire station. These and the final data (Ritzman, 1923) were studied and reported from a single trait point of view. The multiple trait analyses are the subject of this paper. Ritzman observed, however, that the physical makeup, including size, of F_2 individuals appeared to be due to the recombination of body parts of various sizes.

The data of P. E. Neale of the New Mexico Agricultural Experiment Station were used by Stauder (1957) to make estimates of heritability of various body and fleece traits. Single trait studies only were made. It was the opinion of these researchers that little difference existed between the F_1 , F_2 , and F_3 in fiber diameter and fiber length. These data will be examined in this presentation for recombination in the F_2 .

Recombination in Southdown-Rambouillet and Lincoln-Rambouillet Crosses. Figures 2 through 5 are examples of the recombination of quantitative traits in F_2 sheep populations of 41 and 55 in number. Figure 2 shows the plotting of the F_2 dispersion (over the boundaries of the parental populations) for shoulder height and trunk length. In this instance the Rambouillet was generally large in both traits and the Southdown generally small. Animal 34 was as large as the largest Rambouillet in both traits with numbers 32 and 40 nearly as large. At the other extreme, several animals, especially 3, 7, 9, and 29 were typical of the smallest Southdowns in these two traits. Animals 22 and 31 were interesting in that they were near or above the average Rambouillet in shoulder height and near or below the average Southdown in trunk length.

Figure 3, loin width vs. shoulder height, is typical of a number of trait pairs in which each parent was large in one trait and small in the other. In these plottings recombinants rather than parental types appear at the tips of the F_2 recombination spindles. Five animals clearly exceed the loin width of the Southdown with numbers 32, 34, and 40 also exceeding the average shoulder height of the Rambouillet. Conversely, several animals are small in one or both traits with numbers 3 and 29 being just at the lowest extremity of the average Southdown in shoulder height. Plottings of loin width against trunk length revealed a very similar dispersion.

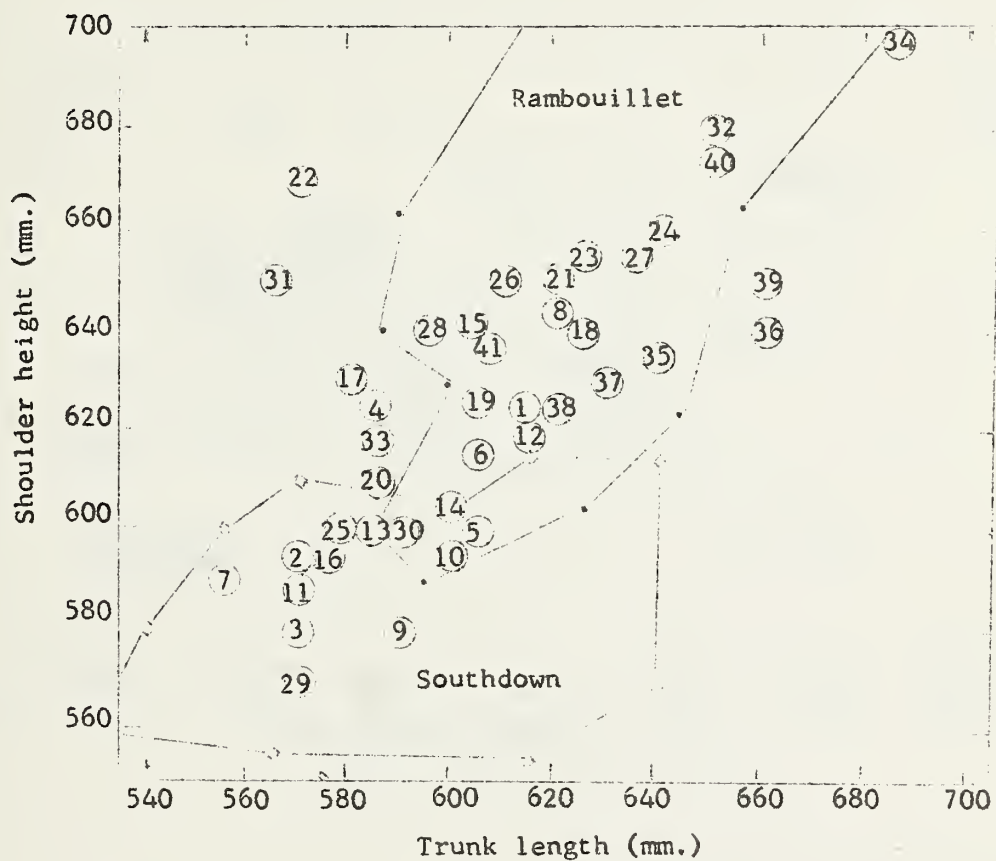


Figure 2.--Recombination of shoulder height and trunk length
in a Southdown-Rambouillet F_2 (n=41)

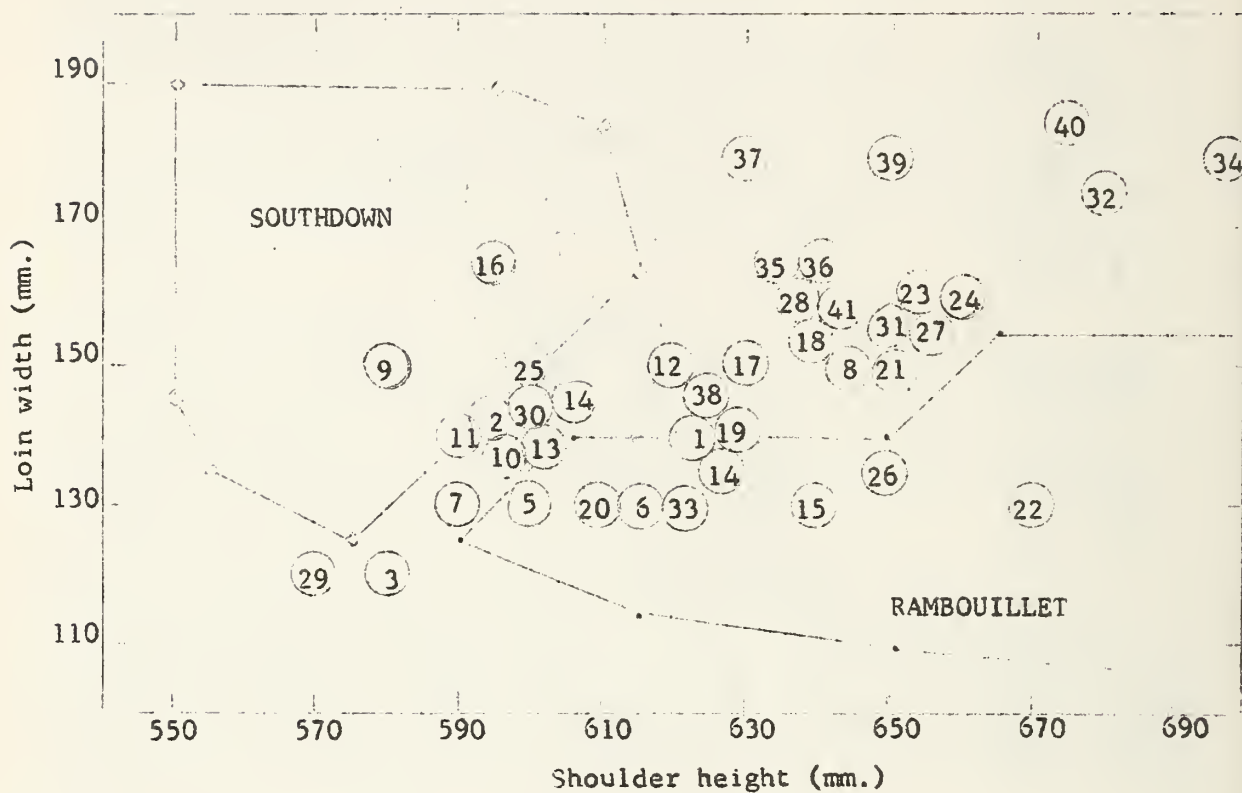


Figure 3.--Recombination of loin width and shoulder height in a Southdown-Rambouillet F_2 ($n=41$)

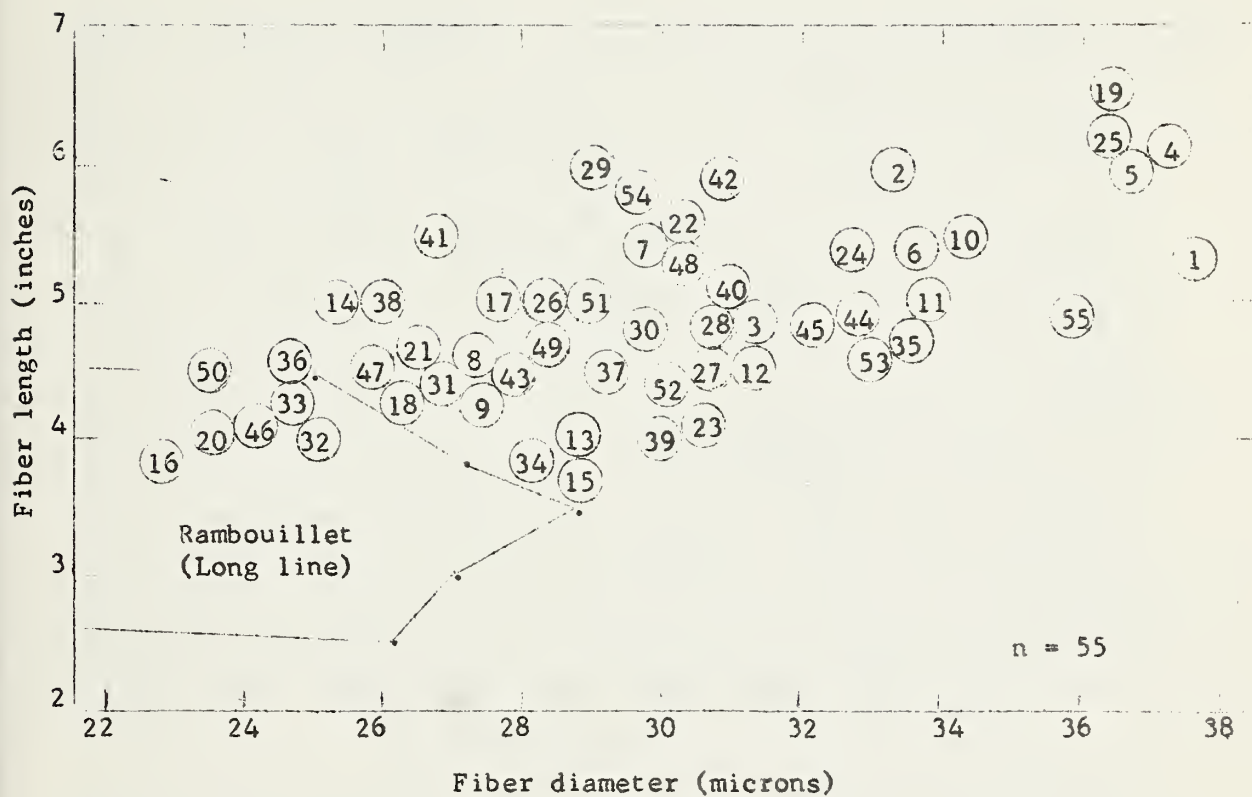
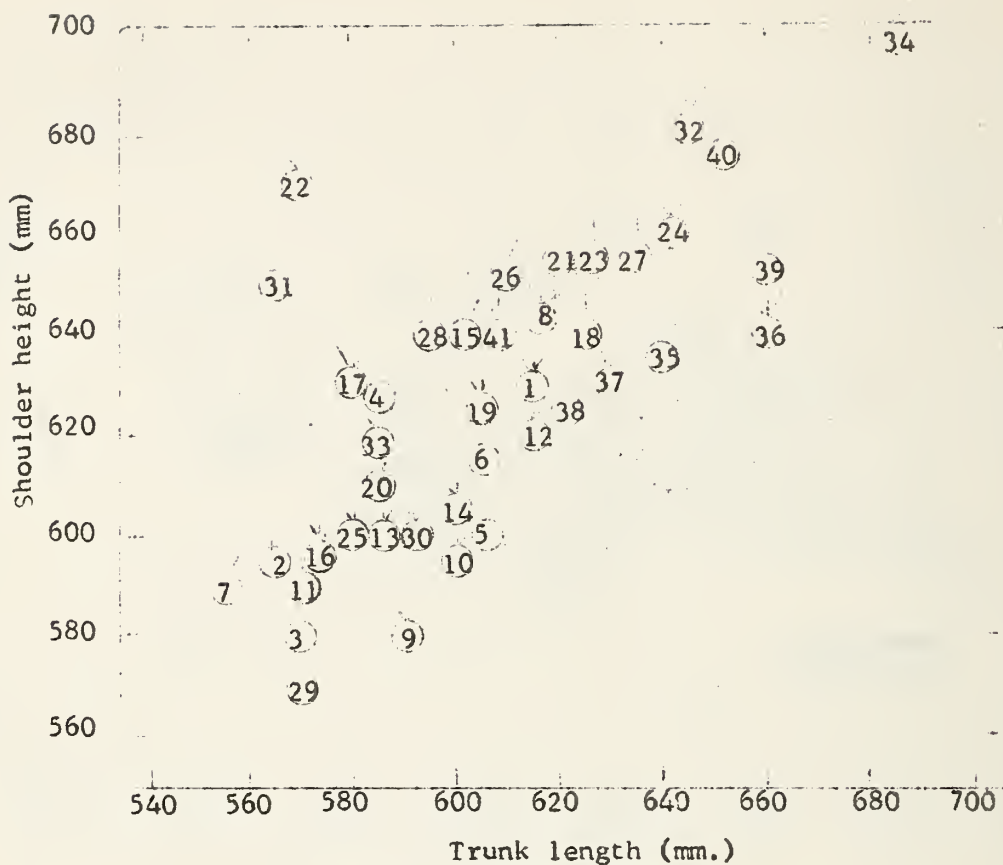


Figure 4.--Recombination of wool fiber length and diameter in a Lincoln-Rambouillet F_2



$\frac{n}{\text{Chest circum. (cc)}}$	$\frac{n}{\text{Loin width (lw)}}$	$\frac{n}{\text{Hind leg circum. (hlc)}}$
13 = 900 mm up	13 = 430 mm up	
15 = 860-880 mm	16 = 400-425 mm	
13 = below 860 mm	12 = below 400 mm	

Figure 5.--Recombination of shoulder height, trunk length, chest circumference, loin width, and hind leg circumference in a Southdown-Rambouillet F_2 ($n=41$)

The F_2 dispersion of hind leg length and hind leg circumference was not quite² as symmetrical. However, two animals appeared which were as short in leg as the Southdown and as slender as the Rambouillet. At the opposite end of the dispersion, two animals appeared which were near the average of one parent breed in one trait and at the highest extreme of the other parent in the second trait.

Figure 4 depicts the plotting of wool fiber length against fiber diameter in a Rambouillet-Lincoln F_2 of size 55. The Rambouillet typically exhibits a relatively short, fine² fiber. There was, unfortunately, only a single Lincoln ram involved so no Lincoln population is described. The breed is characterized by a fleece that is generally longer and coarser than the measurements shown in figure 4. In this F_2 , a half dozen fleeces could be characterized as typically Rambouillet. A few of the opposite extremes might encroach on a Lincoln dispersion but this is uncertain. It is interesting to note, however, that fleeces 29, 2, 5, 4, 25, and 19 are six inches or more in fiber length but vary in fineness from less than 30 to nearly 38 microns--in fact nearly to the coarsest Rambouillet. Those under four inches in length (typically Rambouillet) extend from 22 to 30 microns, each group embracing those grades within the medium to coarse and fine to medium wools, respectively. Conversely, the F_2 fleeces as fine as the Rambouillet average an inch greater length than the Rambouillet. The developers of the Columbia breed, culling fleeces with either coarse or short fibers in order to establish uniformity, discarded many genes for length and fineness simultaneously. Anderson's methods would call for selection along the major portion of the upper periphery of the F_2 spindle in an effort to preserve genetic variation until further recombination had occurred. This assumes that maximum length and fineness are the desired goals of selection.

In reality these various spindles are superimposed on one another in segregating populations. Figure 5 depicts the relationship of five body measurements in the Southdown-Rambouillet F_2 by a slight modification of Anderson's (1957) technique of graphing complex traits. Three additional traits are added to those plotted in figure 2. The F_2 dispersion was divided into upper, middle, and lower thirds with² rays of varying length attached as indicated in figure 5. It happens that the Rambouillet mean fell in the lower third of each of these dispersions and the Southdown means in the upper thirds. Thus, a typical Rambouillet would appear at the upper end of the dispersion being large in shoulder height and trunk length but with no rays attached due to smallness in chest circumference, loin width, and hind leg circumference. Conversely, the typical Southdown would appear in the lower left-hand quadrant but with three full rays attached. As can be seen, no F_2 animals appear which are typical of one parent breed in all five traits.

There is a noticeable tendency for general largeness and general smallness indicating that genes controlling general size may be operating. This could also reflect environmental variations. However, the noticeable deviations from general size patterns are noteworthy. Animal 7 is generally small, but large in hind leg circumference. Animal 16 is a

mixture of large, medium, and small traits as are numbers 31, 22, 28, 26, etc. Number 15 is generally medium or small but had the largest hind leg circumference. Such combinations are difficult to dismiss as being due to environmental variations.

The break up of parental trait associations that is evident suggests that an animal's size is due as much to the recombination of body parts of varying sizes as to genes controlling more general factors influencing size. It also suggests that relatively few linkage blocks exert major effects. Experiments are needed to measure the true breeding merit of these apparent recombinants. Even though the application of known heritability estimates would reduce the magnitude of the deviations from the average, recombination would still be apparent.

The University of Alberta is presently conducting studies preliminary to the establishment of Lincoln and Southdown flocks and the measurement of quantitative recombination and breeding values in the subsequent segregating filial generations.

Possible Uses of Recombination in Beef Cattle Breeding. There is an abundance of evidence that substantial increases in beef cattle production can be gained by the judicious use of crossbreeding (reviewed by Combs, 1962). The future need of the industry will be for a number of superior breeds of sufficiently diverse genetic constitution to achieve maximum heterosis in both the crossbred females and their calves. Since there seems to be a demand for a certain amount of uniformity within the various market classes of cattle, the achievement of this uniformity may require phenotypic similarity between the breeds in such traits as tenderness and palatability, etc. The required phenotypic uniformity among breeds must be achieved while maintaining the genotypic diversity necessary to realize maximum heterosis in the crossbred progeny. This does not mean that all breeds must look alike or perform the same in every trait as uniformity of the market animal can also be achieved through the proper selection of breeds for crossing.

The following traits must be considered if the desired goal of the maximum efficient production of lean, palatable beef is to be achieved:

1. High fertility: Certainly the minimum goal should be a 100% calf crop. In view of continuing developments in the experimental control of reproduction this goal may appear to be too modest a few years hence.
2. Heavy calf at birth: A 90 to 100 lb. calf is 2 to 3 weeks ahead of the 60 to 70 lb. calf. If calving difficulties are excessive, the possibility of shortening the gestation period might be considered. Breed differences of ten days or more have been reported. Selection experiments on gestation length in farm animals could prove fruitful.
3. High calf survival: Crossbreeding appears to be the best breeding method for achieving maximum survival.

4. High milk production: Average weaning weights of 350 to 400 lb. are typical of much of the Western range area. Averages 25% higher have been readily achieved through the use of crossbred females particularly where bulls of Charolais, Brahman, Holstein, or Brown Swiss breeding were used. Individuals and small groups have been reported that average near twice the 350 to 400 lb. figures. It seems possible that the industry might well achieve twice these present weaning weights by genetic means.
5. Rapid gains: Reaching 1,000 lb. weight by 12 months is achieved by the very top individuals. If the steer of tomorrow is a bull, this goal may be more readily achieved.
6. Maximum efficiency: The genetic limits for efficient feed conversion in cattle are not known, but it seems certain that they have not been reached by any large segment of the industry if, indeed, any appreciable selection has been done. Warwick (1958) could find no evidence of genetic gain in efficiency in this century. Experiments revealing breed differences in efficiency such as those at the Texas station showing Brahman superiority in digesting low protein forage should be watched with keen interest.
7. Lean, tender, palatable beef: The continued popularity of beef must surely be due in large part to its palatability despite the great variation within and between breeds in leanness and tenderness. The existence of such variation offers the opportunity for further improving consumer acceptability of beef. The superior consumer acceptance of Jersey carcasses in U.S.D.A. studies should caution beef breeders against complacency toward improvement of the eating qualities of beef.

The cattle breeds available which have been evaluated are:

1. Hereford: Good in gains, carcass tenderness and palatability, satisfactory in fertility, variable in leanness, inferior in milk production. In crossbreeding experiments the Hereford bull generally ranks high as a sire of rapid gaining progeny. The Hereford cow, however, is almost universally inferior in milking ability. Almost every breed of sire used including crossbreds has given some increase in weaning weight over straight Hereford calves. The females from these crosses almost invariably wean substantially heavier calves than do the straight Herefords. Even where Hereford fertility is equal or superior to the Hereford crosses, total calf production is generally lower in the straight Hereford. The consistent results from breeding experiments raise serious doubt that the straightbred Hereford cow can continue indefinitely to be the dominant or even an important factor in the North American commercial beef industry.
2. Angus: Moderate in gain, milk and leanness, good in palatability--short gestation period, and polled. The Angus, like the Hereford, responds well to crossbreeding. The shorter gestation period could be of future experimental and practical interest.

3. Shorthorn: Good in gain and palatability, moderate in milk, inferior in leanness. Experimental results from crossing on Herefords have not been as consistently good as is commonly believed. The Shorthorn breed seems to be experiencing real difficulty due to excessive carcass fat.
4. Charolais: Excels in growth and lean, with good tenderness. The Charolais has shown consistently good results in crossing with other breeds. The crossbred females have been especially productive.
5. Brahman: Excels in lean, good in milk production, but consistently least tender of breeds tested, inferior in feedlot gain. Females are inconsistent breeders, especially if milking. Brahman crosses, especially crossbred females, perform exceedingly well in Canada as well as the Southern United States. Brahman crossbreds are usually intermediate in carcass traits.
6. Holstein and Brown Swiss: High in gains, milk production, leanness, good in tenderness. The dairy breeds may well represent the most valuable untapped germ plasm resource available to the beef industry. Hereford-Brown Swiss crosses at Miles City excelled the Herefords in growth rate and carcass lean. Holstein-Hereford crosses in Alberta equalled or slightly excelled the straight Herefords in preweaning and postweaning gain. The crossbreds had less fat cover and yielded a higher percentage of separable lean but had slightly more kidney fat and graded lower. When backcrossed to the Hereford, however, the Holstein crossbred dams produced calves that were 30% above the Hereford mean in preweaning growth rate and outgained the Herefords slightly in the feedlot. These calves also yielded a higher percentage of separable lean and were not downgraded.
7. Jersey: Excels all breeds in carcass tenderness and palatability and in milk solids; inferior in growth. Despite "poor" conformation, Jersey steers at the University of Alberta yielded 47% hindquarter as compared to 48% in steers of beef breeding. Jersey carcasses were noticeably superior in marbling and tenderness and near ideal in outside cover. Kidney fat was excessive and grades low. It is not seriously proposed that the Jersey be used in commercial crossbreeding although the few crosses with Angus that I have seen at the University of Wyoming and with Charolais and Hereford in Louisiana performed well and in some cases superior to the straight beef calves. However, the 20% superiority in carcass palatability over the Angus and Hereford in U.S.D.A. experiments cannot be ignored by beef cattle breeders intent upon achieving maximum carcass desirability.
8. Exotic stocks: The winter hardiness of the bison and the success achieved with the cattalo at Manyberries, Alberta, should prompt us to search for useful genes wherever they can be found and to seek means of incorporating such genes into cattle populations.

In general, two approaches to improvement are available to beef cattle breeders, improvement of existing breeds for use in crossbreeding and the development of new breeds from gene pools formed by crossing older breeds. The time worn clichés "there are good ones in every breed" and "there is more variation within breeds than between breeds" are no doubt convincing arguments to many that there is sufficient genetic plasticity within any breed to permit effective selection in any desired direction. While there may well be "good ones" in every breed, these arguments ignore the evidence that high milking ability is harder to find in the Hereford than in the Holstein or any other breed. Tenderness appears to be more prevalent in Jerseys, heat tolerance more common to Brahmans, etc. Previous references show that greater phenotypic variance within breeds may well reflect a higher level of homozygosity and thus a reduced potential for effective selection.

The laboratory selection experiments of Brown (1958) and of Falconer and King (1953) reported an increase in estimates of additive genetic variance and a renewed response to selection following the crossing of plateaued populations. Increases in estimates of additive genetic variance have not been found in recent comparisons of livestock gene pools and their parent breeds. However, the shank length selection experiments of Lerner and Dempster (1951) in which the heritability estimate remained unchanged even after the response to selection had ceased, caution against accepting equal heritability estimates as final evidence of equal ability to respond to selection.

It is not suggested that present purebred livestock populations have plateaued in most performance traits. But, how would such a plateau be recognized? Normal environmental variations could obscure a decreased genetic response to selection for many years before it could be recognized. It is the obligation of those engaged in livestock improvement to preclude the occurrence of such a decline in selection response. This would seem to require the periodic renewal of genetic diversity by the formation of genetically divergent gene pools with several stocks in each pool followed by periods of intense selection for the desired traits. Such was the means by which the present breeds were developed.

The use of gene pool foundations promises to offer a greater array of gene combinations than does the narrower purebred base. Certainly, the introduction of the Holstein or Brown Swiss into a beef cattle gene pool establishes a higher potential for ultimate milk production than could be attained by selecting within the existing British beef breeds. To those who fear that high milk production may be undesirable from a management point of view, there have been substantial increases in weaning weights with no accompanying udder problems in the Brown Swiss range herd at Miles City. Dairy cows commonly milk up to 100 lb. of milk per day under twice daily milking without distortion of the teats. Improved udder structure might well be another benefit of utilizing dairy breeds.

The advantage of working with a heterozygous cow herd which the gene pool offers should not be minimized. The heterosis expressed in traits of low heritability such as survival and especially in the early generations make it possible to intensify selection for those traits that will respond more readily. The Illinois station (Dickinson and Touchberry, 1961) reported 32.7 percent mortality in purebreds as compared to only 13.4 percent in young stock and adult cows in Guernsey-Holstein crossbreds.

It may well be that some breeds will continue to be useful in crossbreeding as they are now constituted. The Charolais, Holstein, and Brown Swiss crossbreds would seem to have fewer deficiencies than those by sires of most other breeds. The gene pool, however, offers a means by which the growth and desirable carcass characteristics of the Hereford could be separated from the inferior milking qualities of the breed. The tenderness and high milk solids of the Jersey might be recombined with the rapid growth of other breeds. A number of superior recombinations utilizing existing breeds can be envisioned.

The Canadian Lacombe pig serves as an example of the potential of recombination. The basic gene pool comprised the Landrace, Chester White, and Berkshire. The Chester White disappeared from Canada because it is inferior in carcass meatiness. The Berkshire is inferior in growth rate. Because of inferior performance and Canadian discrimination against black color, the Berkshire accounted for less than one percent of 1962 registrations. Yet, in less than a decade, the Lacombe was evolved which is equal in carcass merit to the Landrace and to the most popular Canadian breed, the Yorkshire, and which reaches market weight an average of 15 days ahead of either of these breeds in Canadian test stations. The genetic influence of the Berkshire is estimated to be three times greater through its contribution through the Lacombe than through its own breed. The greater contribution of the Lincoln sheep through the Columbia is even more striking. Such results caution against the discarding of any breed on its own merits without giving it an opportunity to contribute through gene pool recombination. Breeds such as the Berkshire or the Lincoln--or the Shorthorn--might well regain ascendancy by infusions of genes from breeds that are strong in the deficient traits or by spawning sub-breeds from such crossbred foundations.

The success of the recombination approach lies not in mixing magic portions of each parental breed as some are still attempting with 5/8 British breeding and 3/8 Zebu but involves the breaking up of parental trait associations and the selection of new and superior combinations. This, of course, is the process of improvement in any selected population. The broadly based gene pool simply offers a wider range of recombination possibilities than does the purebred population. The proportion of genes from each contributing parental breed will be whatever best meets the selection criteria imposed. These proportions can only be estimated crudely from the pedigrees of individuals in the advanced generations. Attempts to reconstitute the new breed by mixing certain proportions at the outset misses the essential feature of recombination. The desired recombinant is not composed of a random sample of the genes from each parental breed but of selected gene combinations.

A few courageous, farsighted innovators--perhaps the only beef cattle breeders in this century worthy of the designation "master breeder"--have demonstrated that new breeds can be developed in one man's lifetime that are superior to the parental breeds used. The reference, of course, is to the Klebergs who developed the Santa Gertrudis from a Shorthorn-Brahman foundation and to the Lasaters who developed the Lasater Beefmasters selecting from a Hereford-Shorthorn-Brahman gene pool. It remains for the experiment stations to examine these approaches more critically and develop the most efficient methods of application.

LITERATURE REFERENCES

- Allard, R. W. 1961. Relationship between genetic diversity and consistency of performance in different environments. *Crop Sci.* 1:127-133.
- Anderson, E. 1939. Recombination in species crosses. *Genetics* 24:668-698.
- Anderson, E. 1957. A semigraphical method for the analysis of complex problems. *Proc. Nat. Acad. Sci.* 13:923-927. (Reprinted: 1959. *Technometrics* 2:387-391).
- Anderson, E. and G. L. Stebbins, Jr. 1954. Hybridization as an evolutionary stimulus. *Evolution* 8:378-388.
- Baker, A. L. and W. G. Black. 1950. Crossbred types of beef cattle for the Gulf Coast Region. *USDA Circ. No. 844.*
- Bal, B. S., C. A. Suneson and R. T. Ramage. 1959. Genetic shift during 30 generations of natural selection in barley. *Agronomy J.* 51:555-557.
- Briggs, H. M. 1958. Modern Breeds of Livestock. Macmillan Co., New York.
- Brown, W. P. 1961. Alternative methods of selection applied to plateaued populations of Drosophila melanogaster. Ph. D. Thesis. Purdue Univ., Lafayette, Ind.
- Burns, R. H. 1933. Wool inheritance in Hampshire-Rambouillet crossbreds. *Wyo. Agr. Exp. Sta. Bul.* 196.
- Castle, W. E. 1919. Inheritance of quantity and quality of milk production in dairy cattle. *Proc. Natl. Acad. Sci.* 5:428-434.
- Cole, L. J. and I. Johansson. 1948. Inheritance in crosses of Jersey and Holstein-Friesian with Aberdeen Angus cattle. *Am. Nat.* 82: 265-280.
- Combs, W. 1962. Hybrid vigor--fact or fancy? What can Hereford and Angus breeders expect of crossbreeding? 3rd Annual Beef Cattle Short Course, Univ. of Wyo. (mimeo).

- Combs, W. 1962. Recombination of some quantitative traits in F_2 sheep populations. Ph. D. Dissertation, Univ. Wyo.
- Davenport, G. B. and E. G. Ritzman. 1926. Some wool characters and their inheritance. N.H. Agr. Exp. Sta. Tech. Bul. No. 31.
- Dickinson, F. N. and R. W. Touchberry. 1961. Livability of purebred vs. crossbred dairy cattle. J. Dairy Sci. 44:879-887.
- Dobzhansky, T. H., H. Levene, B. Spassky, and N. Spassky. 1959. Release of genetic variability through recombination. III. Drosophila prosaltans. Genetics 44:75.
- East, E.M. 1916. Inheritance in crosses between *N. Langsdorfii* and *N. Alata*. Genetics 1:311-333.
- England, D. C. 1952. Crossbreeding in swine. Ph.D. Thesis. Univ. of Minn.
- Falconer, D. S. and J. W. B. King. 1953. A study of selection limits in the mouse. J. Genetics 51:562-581.
- Fausch, H. D. 1953. A study of the relationship between inbreeding and variability in the Minnesota No. 1 and No. 2 swine. Ph.D. Thesis. Univ. of Minn.
- Fohrman, M. H., R. E. McDowell, C. A. Matthews and R. A. Hilder. 1954. A crossbreeding experiment with dairy cattle. USDA Tech. Bul. 1074.
- Gaines, W. L., W. W. Yapp and M. H. Campbell. 1925. Crossbreeding experiment has wide scope. 37th Ann. Rpt. Ill. Agr. Exp. Sta. 1923-24:114-116.
- Hanson, W. D. 1959a. The theoretical distribution of lengths of parental gene blocks in the gametes of an F_1 individual. Genetics 44:197-209.
- Hanson, W. D. 1959b. Early generation analysis of lengths of heterozygous chromosome segments around a locus held heterozygous with backcrossing or selfing. Genetics 44:833-837.
- Hanson, W. D. 1959c. Theoretical distribution of the initial linkage block lengths intact in the gametes of a population intermated for n generations. Genetics 44:840-846.
- Hanson, W. D. 1959d. The breakup of initial linkage blocks under selected mating systems. Genetics 44:857-868.
- Hugh, W. I. 1955. A study of the relationship between intensity of inbreeding and amount of variation in economic traits in inbred lines of Poland China swine. Ph. D. Dissertation. Univ. of Minn.

- Kemp, G. A. 1960. Evaluation of the progeny of F_2 tomato selections by replicated field tests. Ph. D. Dissertation. Univ. of Minn.
- Kemp, G. A. 1961. Personal communication. Lethbridge, Alberta Exp.Sta.
- Kuhlman, A. H. 1915. Jersey-Angus cattle. J. Heredity 6:68-72.
- Lasater, T. 1958. Personal communication. Lasater Ranch, Matheson, Colo.
- Lerner, I. M. 1954. Genetic Homeostasis. John Wiley and Sons, New York.
- Lerner, I. M. and E. R. Dempster. 1951. Attenuation of genetic progress under continued selection in poultry. J. Heredity 5:75-94.
- Logan, V. S. and P. E. Sylvestre. 1930. Hybridization of domestic beef cattle and buffalo. Central Exp. Farm, Ottawa. 1937-1949 Prog. Rept.
- Mackenzie, K. J. J. and F. H. A. Marshall. 1917. The inheritance mutton points in sheep. Trans. High. and Agr. Soc. of Scot.
- Nichols, J. E. 1925. Segregation in halfbred sheep. J. Heredity 16:401-408.
- Peters, H. F. 1958. A feedlot study of bison, cattalo, and Hereford calves. Can. J. Animal Sci. 38:87-90.
- Peters, H. F. 1959. Hybridization of domestic beef cattle and American bison. X Internat. Congr. of Genetics, Vol. II.
- Peters, H. F. 1961. Manyberries Agr. Exp. Sta., Alberta. Personal communication.
- Peters, H. F. and K. B. Newbound. 1957. Intra-testicular temperature and fertility of bison, cattalo, and Hereford yearling bulls. Can. J. Animal Sci. 37:14-20.
- Rhoad, A. O. 1955. Breeding Beef Cattle for Unfavorable Environments. Univ. of Texas Press, Austin.
- Ritzman, E. G. 1923. Inheritance of size and conformation in sheep. N. H. Agr. Exp. Sta. Tech. Bul. No. 25.
- Ritzman, E. G. and C. B. Davenport. 1920. A comparison of some traits of conformation of Southdown and Rambouillet sheep and of their F_1 hybrids with preliminary data and remarks on variability in F_2 . N.H. Agr. Exp. Sta. Tech. Bul. No. 15.
- Scott, J. P., J. L. Fuller and J. A. King. 1959. The inheritance of annual seasonal breeding cycles in hybrid Basenji-Cocker Spaniel dogs. J. Heredity 50:225-261.
- Smoliak, S. and J. F. Peters. 1955. Climatic effects on foraging performance of beef cows on winter range. Can. J. Animal Sci. 35: 213-216.

- Stauder, J. R. 1957. Heritabilities of some fleece characteristics and body weight. M.S. Thesis. New Mex. State Univ.
- Stockard, Charles R. 1941. The Genetic and Endocrine Basis for Differences in Form and Behavior as elucidated by studies of contrasted pure-line dog breeds and their hybrids. Wistar Inst. of Anat. and Biol., Phila.
- Sumption, L. J. 1956. An analysis of the early development of the Minnesota No. 3 inbred line of swine. Ph. D. Thesis. Univ. of Minn.
- Suneson, Coit A. 1956. An evolutionary plant breeding method. Agronomy J. 48:188-191.
- Wagnon, K. A., R. A. Albaugh, G. H. Hart. 1960. Beef Cattle Production. Macmillan Co., New York.
- Warwick, E. J. 1958. Fifty years of progress in breeding beef cattle. J. Animal Sci. 17:922-943.
- Winters, L. M. 1954. Animal Breeding. John Wiley and Sons, New York.
- Winters, L. M. 1955. Building breeds as a problem in population genetics. Breeding Beef Cattle for Unfavorable Environments. Univ. of Texas Press, Austin. A. O. Rhoad, Ed.
- Yapp, W. W. 1925. The inheritance of percent fat content and other constituents of milk in dairy cattle. Cattle Breed. Proc. of the Scottish Cattle Breeding Conference. Oliver and Boyd p.328-334.
- Yapp, W. W. 1931. Scientific breeding advanced by inheritance studies Ill. Agr. Exp. Sta. Ann. Rpt. 1931:123-124.

A discussion followed during which Rollins brought up the subject of importation regulations.

Dr. Sumption:

We should first utilize all that we have in this country before we worry about importation. Dr. Clark probably has the information regarding importation, but regulations are not likely to be liberalized too much too fast.

Dr. Combs, have you in Canada given thought to this matter of importation?

Dr. Combs:

There are some things going on to give us hope that regulations will be changed. There are two standards for importation--livestock for improvement and livestock for zoos. There is practically no restriction for bringing animals to zoos, but we cannot bring animals from the same areas for use in scientific work. The regulations are very strict on animals for improvement but not strict on animals for zoos.

Dr. Sumption:

One thing has been explored a bit and that is that in the long view one might establish a breeding center in some other area from which materials might be brought in. The material might be retained at a center for an indefinite time. I haven't heard anything very definite, but several have explored this idea.

Another is the possibility of introducing materials through the germ-free approach--flying in the animal after the Caesarean approach. The idea is being entertained of getting approval for bringing in animals in this manner. How much effort have we put into finding means of overcoming these barriers?

Dr. Clark:

It would be worth exploring.

UNIVERSITY OF ARIZONA

- I. Station: Arizona Agricultural Experiment Station, Tucson, Arizona
- II. Project Title: Breeding and selection of beef cattle for the Southwest
- III. Personnel:

Experiment Station:

O. F. Pahnish, project leader, L. W. Dewhirst, W. H. Hale, F. E. Hubbert, Jr., J. F. Kiernat, A. M. Lane, C. B. Roubicek, E. B. Stanley, and B. R. Taylor

Graduate Students:

E. K. Keating, R. L. Roberson, W. D. Root, and R. L. Taylor

Cooperators:

Apache Indian Agency and Apache Tribe, San Carlos, Arizona.

U. S. Range Livestock Experiment Station, Miles City, Montana
Montana Agricultural Experiment Station, Bozeman, Montana
Wyoming Agricultural Experiment Station, Laramie, Wyoming

U. S. Department of Agriculture, Beef Cattle Research Branch,
Animal Husbandry Research Division, Agricultural Research
Service, Denver, Colorado

R. T. Clark, Coordinator, and J. S. Brinks

IV. Nature and extent of work done this year:

1. The performance of topcross progeny of sires from Miles City lines 1, 6, 9, and 10 has been evaluated and the information is being consolidated for publication. Progeny of sires from other sources were also included in the evaluation. Birth weights and growth traits and grades at periodic intervals from birth to fall yearling age were considered. Data on three crops of calves were involved. Some of the results of this study were summarized in previous annual reports.

2. The breeding program (1962 and 1963) was directed toward the progeny testing of topcross bulls tracing to Miles City lines 1, 6, and 9. Progeny tests on bulls raised in the Apache Tribal Herd but unrelated to the Miles City stock and on bulls recently introduced from private sources are included.

3. The accumulation of data for the evaluation of maternal qualities in topcross females was continued.

4. Collection of data for the genetic evaluation of blood constituents was continued.

5. Emphasis was placed on the estimation of heritabilities of economically important traits (birth to two years of age) in range beef cattle, and upon the computation of genetic, environmental, and phenotypic correlations among these traits.

6. Genetic evaluation of plasma cholesterol levels in range cattle were undertaken. Some of the parameter estimates have been completed.

7. A section on hereditary abnormalities of beef cattle was contributed for the beef cattle breeding bulletin being prepared by the Western region.

V. Summary of progress:

Heritabilities of growth traits, grades, and condition scores of range cattle were estimated by the paternal half-sib method. The data represented four calf crops. The progeny of 17 sires were used and estimates were computed within sex of progeny (bulls and heifers). The data were analyzed in four blocks, namely: (1) weaning, (2) end of first winter after weaning, (3) fall yearling age, and (4) end of second winter. This permitted the use of the maximum amount of data at each end point. The heritability estimates, grouped according to the analytical blocks from which they were derived, are summarized in table 1. Estimates obtained from the fourth block of data are tentative pending complete verification of computations.

On the basis of overlap in 95 percent confidence intervals, the analogous within-sex estimates of heritabilities (table 1) could be considered in perhaps all comparisons as estimates of the same population parameter. On the other hand, the higher estimates derived from the heifer data for preweaning and weaning traits (gain, weight, grade, and condition) are consistent with results previously reported and cited by Pahnish et al. (1961) (J. Animal Sci. 20:454). Results to the contrary have also appeared (Meyerhoeffer et al., 1963, J. Animal Sci. 22:240).

In general, heritability estimates for growth traits measured subsequent to the end of the first winter were appreciably higher than estimates for growth traits measured at or prior to the end of the first winter (table 1). Heritability estimates for grade and condition were not so consistent in trend.

Correlations of growth rates of heifers during three periods between birth and fall yearling age are summarized in table 2. The genetic correlations of daily gain from birth to weaning with daily gain during the first winter after weaning was near zero. The genetic correlation of daily gain during first winter with subsequent rate of gain was low and negative. The period rates of gain most highly correlated genetically (0.38) were daily gain from birth to weaning and daily gain from end of first winter to fall yearling age. An estimate of the correlated response indicated that indirect selection for rate of gain following first winter by selecting for preweaning rate of gain would be about one-third as effective as direct selection for rate of gain following first winter.

Table 1.--Heritability estimates from paternal half-sib correlations

Trait ^a	Estimates ^b	
	Bulls	Heifers
Birth weight	0.32**	0.14*
Gain, birth to weaning	.01	.25**
Weaning weight	.05	.23**
Weaning grade	.08	.24**
Weaning condition score	.06	.32**
Gain, birth to end of first winter	.11	.20**
Gain, weaning to end of first winter	.32**	.15*
Weight, end of first winter	.20*	.21**
Grade, end of first winter	.04	.13*
Condition score, end of first winter	.17*	.16*
Gain, birth to fall yearling age	.61**	.43**
Gain, weaning to fall yearling age	.57**	.32**
Gain, end of first winter to fall yearling age	.49**	.32**
Fall yearling weight	.64**	.40**
Fall yearling grade	.16*	.13
Fall yearling condition score	.31**	.11
Gain, birth to end of second winter	.82**	.49**
Gain, weaning to end of second winter	.71**	.43**
Gain, end first winter to end of second winter	.62**	.38**
Gain, fall yearling age to end of second winter	.20*	.52**
Weight, end of second winter	.87**	.52**
Grade, end of second winter	.18	.31**
Condition score, end of second winter	.13	.53**

^aGains refer to daily gains. Grades, scored on 15 point basis, were committee averages. Condition scores, on 15 point basis ranging from excellent to poor, were committee averages.

^bAsterisks indicate significance of sire effects from variance analyses (** = $P < .01$; * = $P < .05$).

Table 2.--Correlations of daily gains measured on range heifers^a

		Daily gains	
		Period 2	Period 3
Daily gains, Period 1	G	0.04	0.38
	E	-.37	.14
	P	-.31	.21
Daily gains, Period 2	G		-.14
	E		-.07
	P		-.09

^aPeriods 1, 2, and 3 are periods from birth to weaning, from weaning to end of first winter after weaning, and from end of first winter to fall yearling age, respectively. G, E, and P denote genetic, environmental, and phenotypic correlations, respectively.

Correlations of weight, grade, and condition of heifers at weaning and fall yearling age are tabulated in table 3. Grades were quite highly correlated (genetically, environmentally, and phenotypically) with contemporary condition scores. Weaning grade was highly correlated genetically with fall yearling grade but not with fall yearling condition. Weaning condition was, likewise, highly correlated genetically with fall yearling grade but not with fall yearling condition. Genetic correlations of grades or condition scores with contemporary weights were low or moderate. Environmental factors apparently were the main contributors to the relationships between grades or condition scores and contemporary weights.

Table 3.--Correlations of weight, grade, and condition measured on range heifers^a

		Weaning		Fall yearling	
		Grade	Condition	Grade	Condition
Birth weight	G	-.32	-.11		
	E	.25	.21		
	P	.14	.14		
Weaning weight	G	.21	.41		
	E	.64	.60		
	P	.54	.55		
Weaning grade	G		.96	1.00	0.11
	E		.78	.26	.36
	P		.83	.38	.32
Weaning condition	G			.78	.25
	E			.29	.37
	P			.38	.33
Fall yearling weight	G			.08	.11
	E			.37	.51
	P			.29	.40
Fall yearling condition	G			.92	
	E			.64	
	P			.68	

^aG, E, and P denote genetic, environmental, and phenotypic correlations, respectively.

The means and standard deviations of plasma cholesterol concentrations from the unadjusted data collected at weaning and fall yearling ages are shown in table 4. Variables accounting for some of the observed variation are shown in the variance analyses (table 4). Both heritability estimates obtained from the heifer data were considerably higher than the estimate obtained from the bull data collected at weaning age. The genetic variance estimated from the bull data at fall yearling age was negative.

Table 4.--Means, variance analyses, and heritability estimates for plasma cholesterol concentrations at weaning and fall yearling age.
(Bulls and Heifers)^a

Source of variation	Weaning age		Fall yearling age	
	d.f.	M.S.	d.f.	M.S.
<u>Heifers</u>				
Years	1	120,607**	1	12,434**
Age of dam	7	900	7	401
Sire	11	3,451**	11	1,135*
Age of calf	1	2,116	1	765
Error	146	1,180	112	517
Heritability estimates		0.46		0.37
Means and standard deviations		141±46		116±26
<u>Bulls</u>				
Years	1	94,855**	1	11,118**
Age of dam	7	947	7	1,163
Sire	11	1,775	11	606
Age of calf	1	5,801*	1	862
Error	146	1,094	78	996
Heritability estimates		0.16		Neg. genetic variance
Means and standard deviations		145±43		124±34

^a** P < .05; * P < .01. Means are from unadjusted data. Heritabilities estimated by paternal half-sib method.

Correlations of plasma cholesterol concentrations of range heifers at weaning with fall yearling traits are shown in table 5. The genetic correlations of plasma cholesterol concentration at weaning with fall yearling weight and with daily gain from birth to fall yearling age were relatively high and positive. That one might anticipate heritable influences on plasma cholesterol concentrations and positive correlations of plasma cholesterol with growth traits is suggested in the literature (Claesson and Hansson, 1957, Acta Agr. Scandinavia 6:383; Cherms *et al.*, 1960, Poultry Sci. 39:889; Colby *et al.*, 1950, J. Animal Sci. 9:652).

Table 5.--Genetic, environmental, and phenotypic correlations of plasma cholesterol concentrations at weaning with fall yearling traits in heifers

Fall yearling traits						
		Plasma cholesterol	Weight	Condition	Daily gain	
					Birth to yrl. age	Weaning to yrl. age
Plasma	G	1.03	0.69	-.78	0.59	0.14
cholesterol at	E	-.31	-.46	.50	-.41	-.09
weaning age	P	.17	.03	.06	.04	-.00

Table 6.--Genetic (G), environmental (E), and phenotypic (P)
correlations with heifer and bull data combined

		Daily gain birth to weaning	Weaning weight	Weaning grade	Weaning condition
Birth weight	G	0.43	0.62	-.35	-.12
	E	0.09	0.31	0.23	0.19
	P	0.14	0.36	0.12	0.12
Daily gain, birth to weaning	G		0.92	0.16	0.51
	E		1.01	0.54	0.51
	P		1.00	0.49	0.51
Weaning weight	G			0.07	0.42
	E			0.57	0.50
	P			0.49	0.49
Weaning grade	G				0.95
	E				0.77
	P				0.80

Table 7.--Estimates of direct and correlated responses from single trait selection (Heifer and bull data combined)^a

Selected trait ^b		Birth weight lb.	Daily gain birth to weaning lb.	Weaning weight lb.	Weaning grade score	Weaning condition score
Birth weight $\hat{\sigma}_p = 9.63$	(a)	2.21	0.013	4.8	-.07	-.03
	(b)	0.23	0.07	0.11	-.07	-.03
	(c)	1.00	0.65	0.83	-.39	-.14
Daily gain, birth to weaning $\hat{\sigma}_p = 0.185$	(a)	0.66	0.020	4.9	0.02	0.07
	(b)	0.07	0.11	0.11	0.02	0.07
	(c)	0.30	1.00	0.84	0.11	0.33
Weaning weight $\hat{\sigma}_p = 44.4$	(a)	1.03	0.020	5.8	0.01	0.07
	(b)	0.11	0.11	0.13	0.01	0.07
	(c)	0.47	1.00	1.00	0.06	0.33
Weaning grade $\hat{\sigma}_p = 1.04$	(a)	-.67	0.004	0.5	0.18	0.17
	(b)	-.07	0.02	0.01	0.17	0.18
	(c)	-.30	0.20	0.09	1.00	0.81
Weaning condition $\hat{\sigma}_p = 0.94$	(a)	-.26	0.015	3.2	0.19	0.21
	(b)	-.03	0.08	0.07	0.18	0.22
	(c)	-.12	0.75	0.55	1.06	1.00

(a) Response in actual units of measurement.

$$\Delta G_u = \sqrt{h_s^2 h_u^2} r G_s G_u \sigma P_u$$

(b) Response in standard deviation units.

(c) Response expressed as the ratio $\frac{\Delta G_u}{\Delta G_s}$.

VI. Application of findings:

Progress that can be made through selection for economically important traits is largely dependent upon the amount of variation present, the heritabilities of these traits, and the relationships between the traits involved. The estimates completed during the past year provide information concerning the heritabilities of economically important traits and the correlations among these traits as measured in range cattle. Information of this type on postweaning traits measured under Southwestern range environments is limited. Most of the information to date on the postweaning traits of bulls has been obtained under feedlot conditions.

The plasma cholesterol study provides information concerning mean values, variation in what are presumably normal values for range cattle, and some of the factors contributing to the existing variation in cholesterol values. Such data should provide useful background information for other beef cattle investigations. Although based upon limited data, the correlations of cholesterol values with economically important traits provide preliminary information concerning the probable value of cholesterol concentration as an aid in identifying animals that are genetically superior for important traits.

VII. Work planned for the future:

Consolidation and publication of information on growth characteristics of sire progenies.

Completion of the correlation studies now in progress. Computations, through the basic variance and covariance analyses, are nearly complete. All correlations of probable importance among the traits for which heritabilities were estimated (table 1) will be considered.

Statistical evaluation of data on blood constituents as appropriate block of data become available. Blood hemoglobin and plasma phosphorus values are being treated statistically at the present time.

Continuation of progeny tests on topcross bulls tracing to Miles City lines and on other bulls that have been or will be introduced into the herd.

Continue the evaluation of maternal qualities in topcross females.

Subject to the approval of all parties concerned, a test of the relationship between maternal qualities and postweaning gain is anticipated.

VIII. Publications:

Pahnish, O. F. 1962. "Management" dividend from Arizona range--17 percent more calves. West. Livestock J. 40(41):251.

Pahnish, O. F., R. L. Roberson, R. L. Taylor, J. S. Brinks, R. T. Clark, and C. B. Roubicek. 1963. Genetics of growth traits in range cattle. Amer. Soc. Anim. Sci. West. Sect. Proc. 14.

Roberson, Robert L., O. F. Pahnish, R. L. Taylor, J. S. Brinks, R. T. Clark, and A. M. Lane. 1963. Genetics of grade, condition, and weight in range cattle. Amer. Soc. Anim. Sci. West. Sect. Proc. 14.

Taylor, R. L., O. F. Pahnish, Farris Hubbert, Jr., W. H. Hale, R. L. Roberson, and J. S. Brinks. 1963. Genetics of plasma cholesterol in range cattle. Amer. Soc. Anim. Sci. West. Sect. Proc. 14.

IX. PROJECT SUMMARY

Cattle Inventory

Purebred Arizona Agricultural Experiment Station

Breed	Hereford
Line	Apache Tribal Herd
Station	Arizona
Bulls (12 mo. or over)	90
Cows (2 yrs. or over)	548
Heifers (yearling)	145
Bull Calves	180
Heifer calves	184
Estimated cash value ¹	\$275,000

¹ Cooperative project. No accurate method of determining percentage use for breeding project.

Land, physical facilities, and equipment

	Amount	Actual cash value	Percentage used for breeding project ¹
Apache Reservation:			
Land	35 sections	\$560,000	
Fencing	65 miles	31,850	
Corrals and scales		8,000	
Water supply		16,000	
Total		\$615,850	
Experiment Station:			
Laboratory facilities		\$25,000	25

¹ Owned by private operators. No accurate method of determining percentage use for breeding project.

Arizona Agricultural Experiment Station

Cow Production

1962 calf crop

Breed		Hereford	
Line		Apache Tribal Herd	
Cows bred to calves as 2-year-olds		None	
Calves born from 2-year-olds		None	
Cows bred to calve at 3 years and up		405	
Calves born from 3-year-olds and up			
Alive		308	
Dead		16	
Total		324	
Calves weaned			
Percent calf crop			
Birth ¹		76%	
Weaning ²		70%	

	Bulls		Heifers	
	No.	Av.	No.	Av.
Birth weight	152	78	156	76
Weaning age	245		245	
Weaning weight	125	490	129	443
Adjusted weaning weight ³	125	482	129	436
Weaning score				
Condition		10		11
Conformation ⁴		11		11

¹ Calving percentage based on calves born alive and exposed cows still in herd during calving season.

² Weaning percentage based on calves weighed at weaning time and cows in herd during calving season, less cows sold before weaning with calves at side.

³ Weights adjusted to 230 days of age and to a mature dam basis.

⁴ Score based on feeder grade. Scores of 10, 11, and 12 are low, middle, and high choice, respectively.

UNIVERSITY OF CALIFORNIA

- I. Station: California Agricultural Experiment Station, Davis, California
- II. Project title: Genetic control of hereditary deficiencies in beef cattle with special emphasis upon dwarfism
- III. Personnel:

California Experiment Station:
P. W. Gregory, F. D. Carroll, L. M. Julian, W. S. Tyler,
T. J. Hage, and Clyde Stormont

U. S. Department of Agriculture, Agricultural Research Service,
Denver, Colorado:
R. T. Clark, regional coordinator, J. S. Brinks
- IV. Nature and extent of the work done this year:

Most of the research is a continuation of the work that has been in progress for the past several years but the tempo of the genetic tests has been increased, more comprehensive biochemical studies were undertaken, new histopathological studies have been added, and the laboratory services provided for breeders and artificial insemination associations have been continued and this has provided several specimens of great importance.

1. Sufficient diagnostic criteria are now available for recognizing achondroplastic expression in several specific areas of the skeleton and in differentiating several achondroplastic types all of which are conditioned by heredity; weights and body measurements are helpful in supplementing the anatomical criteria in the diagnosis of different types of achondroplasia, thus improving the accuracy of the progeny test. With the analytical characteristics now developed it is possible to classify most of the progeny from matings and to recognize rarer types of achondroplastic segregates.
2. An analysis of weight and body measurements of registered Hereford cows at this station selected and rejected for breeding has been made which sheds light on the nature of segregation within a herd; there is evidence that deleterious genes are implicated and they may also be a part of the genetic load that all organisms which have been subjected to careful scrutiny are known to possess.
3. The progeny tests for dwarfism and achondroplasia under controlled conditions, underway since 1952, are complete except for the autopsy of a few test progeny to be done at 15 months of age. These tests indicate that classification of progeny by visual inspection is inaccurate and unreliable. Accuracy can be greatly increased by employing reliable diagnostic anatomical criteria in classification. These results clearly reveal why pedigree clean lines break down and produce dwarfs and why a bull assumed to be clean by progeny test, in which the test progeny are classified by visual inspection, may later sire dwarfs.

4. The analyses of the test progeny of the Oregon Hereford bull progeny tested for achondroplasia at this station on small segregate tester cows are now complete. Only 10 test progeny were produced, one was a typical long-headed dwarf possessing the characteristic achondroplastic lesions of that type, two others had lesions of achondroplasia; the seven remaining were subnormal in size but did not have recognizable lesions of achondroplasia. The progeny test of the New Mexico bull to determine the relationship between achondroplasia and hydrocephalus will be complete when six living progeny, now 9 months of age and older, are autopsied at 16 months of age. Thus far, the bull has not sired a brachycephalic dwarf but he has sired progeny which exhibit early and intermediate spheno-occipital fusion, at least one hydrocephalic calf, and a number of compressed type progeny. A number of the progeny have one or more metacarpal indices in the dwarf range.

5. A summary of hydrocephalic calves from the field reveals that most come from herds that previously had a dwarf problem. In a few cases the occurrence of dwarfs ceased but were replaced with about the same percentage of hydrocephalic calves. Often hydrocephalic calves are typical dwarfs with premature S-O fusion and metacarpal indices typical of dwarfs. One bull sired both typical brachycephalic dwarfs and typical hydrocephalic dwarfs. Some of the lines maintained at the California Station that produce typical dwarfs sporadically produce a hydrocephalic calf some with, but others without, characteristics of achondroplasia. Most brachycephalic achondroplastic dwarfs have enlarged lateral ventricles of the brain thus showing a degree of hydrocephaly. Pediatricians recognize that human achondroplastics possess varying degrees of hydrocephaly. We have observed hydrocephalus in Herefords, Angus, and Jerseys, all of which possessed the typical lesions of achondroplasia.

6. A new achondroplastic type:

Now that the anatomical lesions of the common achondroplastic mutants are sufficiently well defined to permit classification of each type, it is possible to recognize new achondroplastic types that are less commonly observed due to low viability or infrequent occurrence. There is a new small type with slender long bones, an extremely complicated curvature of the spine, and early fusion of the spheno-occipital synchondrosis which is slightly later than that of the brachycephalic type. Because of the fine bones, the metacarpal indices fall in the range of controls. This type has been observed in the Hereford and Angus breeds. The recognition of this form will permit a refinement of the metacarpal indices (Tyler et al., 1961, Am. Jour. Vet. Res.).

7. Further investigations were undertaken in collaboration with Jary S. Mayes of the Department of Biochemistry of Michigan State University concerning the relationship of the brachycephalic dwarf in cattle to Hurler's syndrome in man. Urine samples were collected from both sexes of 19 brachycephalic dwarfs, 17 dolichocephalic dwarfs, and 18 controls, age ranges were from 2 months to 7 years. There were no differences

between the mucopolysaccharide fractions of the three stocks tested and in no way did they resemble values given for the two types of Hurler's syndrome. Age had an effect but it disappeared soon after 12 months.

V. Application of findings:

The evidence that the brachycephalic dwarf is not homologous with Hurler's syndrome in man is of general interest and should be of importance in human genetics, biochemistry, and metabolic disorders in general. It is certain that in progeny testing for dwarfism that classification of test progeny by visual inspection is ineffective and subject to great error. This shortcoming alone is sufficient to account for the number of bulls that come to our attention which are assumed to be dwarf free by such a progeny test but later break down and produce dwarfs; this could also account for reports that come to our attention of a number of animals from pedigree clean lines that break down and produce dwarfs. These results suggest that genetic research in beef cattle is not sufficiently basic to resolve problems of herd deterioration, abortions, early death losses, and genetic load, problems of paramount interest to producers and breeders.

VI. Work planned for the future:

The simple mutants, brachycephalic and dolichocephalic dwarfs, and the complicated mutants, Dexter, comprest, and compact, all suffer from achondroplasia and are related biologically and genetically. Each mutant affects size, conformation, herd deterioration, and heterosis. Attention will be directed to a clearer understanding of the genetic and biological relationships of these mutants and how these complexes may influence practical problems of production.

VII. Publications:

None.

VIII. University of California achondroplastic herd inventory - June 1, 1963.

<u>Type</u>	<u>No.</u>	<u>Totals</u>
1. Brachycephalic dwarfs		
Females, mature	31	
Females, yearlings	2	
Bulls, mature	3	
Bulls, yearlings	1	37
2. Dolichocephalic dwarfs (heavy bone)		
Females, mature	18	
Females, yearlings	3	
Bulls, mature	1	22

University of California achondroplastic herd inventory (Continued)

<u>Type</u>	<u>No.</u>	<u>Totals</u>
3. Dolichocephalic dwarfs (light bone) Females, mature	3	3
4. Comprest (descend. of Colo. Dom. 68) Females, mature Females, yearlings	3 1	4
5. Recurrent comprest Females, mature Females, yearlings Bulls, yearlings	8 2 4	14
6. Synthetic comprest Females, mature Females, yearlings Bulls, mature	14 1 1	16
7. Dexter Females, mature (synthetic) Females, mature ("Kerry" type) Females, yearlings Females, mature (reg. Dexter) Bulls, mature	7 13 5 4 2	31
8. Bulls, mature (not listed elsewhere)	3	3
9. Yearlings (to be sold or autopsied at 16 months) Females Bulls	13 5	18
10. 1963 calf crop Females Bulls	18 29	47
Total		195

IX. Summary of progeny test matings:

	<u>No.</u>
1. Bulls, conventional X conventional carriers	28
2. Oregon bull X small testers cows	10
3. New Mexico bull X	
a. brachycephalic dwarf	11
b. comprest	13
c. recurrent comprest	14
d. own daughters	18

Summary of progeny test matings (Continued):

	<u>No.</u>
4. Brachycephalic bull ×	
a. brachycephalic dwarf	2
b. conventional	5
c. comprest (desc. of Colo. Dom. 68)	19
d. recurrent comprest	24
e. synthetic comprest (from heavy bone dam)	2
f. synthetic comprest (from light bone dam)	2
g. dolichocephalic dwarf (heavy bone)	20
h. dolichocephalic dwarf (light bone)	18
5. Dolichocephalic bulls (heavy bone) ×	
a. brachycephalic dwarf	14
b. compact-comprest F ₁	2
c. recurrent comprest	1
d. synthetic comprest (from heavy bone dams)	4
e. synthetic comprest (from light bone dams)	8
f. dolichocephalic dwarf (heavy bone)	4
g. dolichocephalic dwarf (light bone)	7
6. Recurrent comprest bull 100 ×	
a. brachycephalic dwarf	21
b. conventional carriers	20
c. recurrent comprest	17
d. dolichocephalic dwarf (heavy bone)	1
7. Synthetic comprest bulls ×	
a. brachycephalic dwarf	43
b. synthetic comprest (from heavy bone dams)	34
c. synthetic comprest (from light bone dams)	28
d. dolichocephalic dwarf (heavy bone)	15
e. dolichocephalic dwarf (light bone)	9
8. Synthetic comprest bull 111 × miscellaneous small segregates	10
9. Subnormal bull 252 × miscellaneous small segregates	8
10. Dexter bull ×	
a. brachycephalic dwarf	12
b. comprest	12
c. recurrent comprest	7
d. dolichocephalic dwarf (heavy bone)	12
e. dolichocephalic dwarf (light bone)	12
f. registered Dexter	5
g. "synthetic" Dexter	8
h. Dexter daughters	7
i. Kerry daughters	10
j. unclassified	9

Summary of progeny test matings (Continued):

	<u>No.</u>
11. Small type segregate, 529 x	
a. brachycephalic dwarf	3
b. dolichocephalic dwarf (heavy bone)	4
c. dolichocephalic dwarf (light bone)	2
12. Tall light bone segregate, 590 x	
a. brachycephalic dwarf	3
b. comprest	8
c. recurrent comprest	3
Total progeny	554

UNIVERSITY OF CALIFORNIA

- I. Station: California Agricultural Experiment Station, Davis, California
- II. Project title: Studies of heterotic effects in crosses of the Angus, Hereford, and Shorthorn breeds (Project 1216)
- III. Personnel:

Experiment Station:
W. C. Rollins, project leader, F. D. Carroll, R. G. Loy, Allan Grunder, Deborah Sittmann, and K. A. Wagon

U. S. Department of Agriculture, Agricultural Research Service, Denver, Colorado:
R. T. Clark, regional coordinator, and J. S. Brinks
- IV. Nature and extent of work done this year:

a. Artificial insemination of virgin heifers resulted in a conception rate to first service of 43.2% over all breeds. Breeding for crossbred embryos appeared to have no significant advantage over those for straightbred (44.1 vs. 41.4). There appeared to be no differences between the two bulls used although this is confounded by the use of both liquid and frozen semen from each bull.

Summarization of remaining data collected is not completed.

b. All of the foundation heifers in the experiment were blood typed as were the two Angus bulls used in the first breeding season, just completed.

c. Pasture and range development, fencing, construction of shelters and corrals, etc., is proceeding at the university's newly acquired Sierra Foothill Range Experiment Station. Space and facilities are being specifically set aside for animals in this experiment that will be sent to or produced there. A projected inventory of such animals is reported as table 1.
- V. Summary of progress and conclusions to date:

Too early to report.
- VI. Application of findings:

Too early to report.
- VII. Work planned for future:

a. Studies of reproductive performance to be conducted at the Davis location will include effects of crossbreeding on (1) conception rates

Table 1.--Schedule of (1216) heifers available for range abortion study. (Estimated numbers are based on a 70% calf crop. In any one year an unfavorable sex ratio could reduce the numbers.)

July '64	July '65	Jan. '66	July '66	Oct. '66	Jan. '67	July '67	Oct. '67	Jan. '68	Oct. '68
(5) 8 mo. AA	(5) 20 mo. AA	Breed	(5) 20 mo. HA	A & B	Breed	(5) 20 mo. SA	C & D	Breed	E & F
(5) 8 mo. AH	(5) 20 mo. AH	A & B	(5) 20 mo. HH	calve	C & D	(5) 20 mo. SH	calve	E & F	calve
(5) 8 mo. AS	(5) 20 mo. AS	as 2-yr-olds	(5) 20 mo. HS	as 2-yr-olds	as 2-yr-olds	(5) 20 mo. SS	as 2-yr-olds	as 2-yr-olds	
Arrive from Davis	Arrive from Davis	2 Angus bulls	Arrive from Davis		2 Hereford bulls	Arrive from Davis		2 Shorthorn bulls	
A	B		D			F			
(5) 8 mo. HA	(5) 8 mo. HA		(5) 8 mo. SA			Supply of			
(5) 8 mo. HH	(5) 8 mo. HH		(5) 8 mo. SH	A & B		calves from		A, B, C, & D	
(5) 8 mo. HS	(5) 8 mo. HS		(5) 8 mo. SS	available		Davis cows		available	
Arrive from Davis	Arrive from Davis		Arrive from Davis	for		could		for	
C	E			breeding		continue		breeding	
				If Desired		If Desired		If Desired	

and (2) later pregnancy losses. Data collected will provide information on effects of crossbred embryos, crossbred dams, and interactions of the two. Other general reproductive data to be collected will include age and weight at puberty.

Studies of post-partum reproductive performance will constitute an important aspect of the reproductive phase. Investigation of effects of genetic and nutritional factors and their interactions are planned. Initially, possible differences between two levels of energy intake initiated just prior to calving and continued through the breeding season will be studied. End points to be used in this phase will include intervals from calving to: (1) first ovulation, (2) first estrus, (3) uterine involution, and (4) conception. (It is hoped that parallel investigations may provide information on effects of specific agents on interval post-calving to uterine involution.)

b. The experimental plan originally called for castrating all the male offspring produced at Davis. Half were and half were not to receive stilbestrol in order to investigate the interaction of the stilbestrol effect with a heterotic effect. Now it is planned to castrate only half the male offspring and grow the rest out as bulls. The steers would receive stilbestrol but not the bulls.

c. The Animal Husbandry Department in cooperation with the School of Veterinary Medicine is undertaking an extensive study of causes of reproductive losses in range cattle. Managerial, nutritional, and genetical aspects are being considered. Although a formal project is being set up, this project (1216) will be involved in some aspects of the study. The interaction between mating system (crossbreeding vs. straightbreeding) and treatment (different levels of exposure to "causes" of reproductive losses) is a fruitful genetical line of investigation. Table 2 symbolizes pertinent types of comparisons that are planned for heifers produced at Davis and later moved to the Sierra Foothill Range.

d. All animals in the experiment will be blood typed. Correlations between blood type and production traits will be estimated both with respect to specific alleles and level of heterozygosity.

VIII. Publications:

Loy, R. G. 1963. Artificial insemination in the University beef herd and breeding results in estrus synchronization field trials using Provera and artificial breeding. Animal Husbandry Department and Agricultural Extension Service, University of California. Beef Cattle Day 1963:13. Mimeog. Rpt.

Wagon, Kenneth A. and W. C. Rollins. 1962. Factors affecting fill and consequently overnight shrinkage in range cattle. J. Range Mangt. 15:158-161.

Table 2.--Type of comparisons to be made for each of three breeding seasons

		Length of period of adaptation to range conditions prior to being bred as 2-year-olds	
		1-1/2 years	1/2 year
Breeding of heifers	Straightbred (SB)	(5)* P_1	(5) P_2
	Crossbred (XB)	(10) P_3	(10) P_4

Comments

P_1 = Reproductive performance of indicated group

P_1 vs P_2 Difference in adaptability due to time and/or management

P_3 vs P_4 Difference in adaptability due to time and/or management

P_1 vs P_3 Difference in adaptability due to XB vs SB

P_2 vs P_3 Difference in adaptability due to XB vs SB

$(P_1 - P_2)$ vs $(P_3 - P_4)$ Interaction between breeding and management

XB heifers will have backcross calves and SB heifers will have SB calves

* With these small numbers per year the animals should be closely observed and fully exploited.

IX. PROJECT SUMMARY

Cattle Inventory

California Agricultural Experiment Station

Breed	Angus	Hereford	Shorthorn
Purebred	10	23	30
Grade	19	5	0
Estimated cash value - \$21,513.60			

Land, physical facilities, and equipment used - June 1963

	Number	Actual Cash value	Percentage used for breeding project
Barns and corrals	3	\$100,000	75
Irrigated pastures	46 acres		100
Drylots and pastures	14 acres		100

UNIVERSITY OF CALIFORNIA

- I. Station: California Agricultural Experiment Station, Davis, California
- II. Project title: A comparison of the live performance and carcass traits of crossbred Hereford-Angus calves and Hereford-Charbray calves with calves of their respective parental breeds (Project 1938)
- III. Personnel:
 - Experiment Station:
W. C. Rollins, project leader, F. D. Carroll, Allan Grunder, and Deborah Sittmann.
 - U. S. Department of Agriculture, Agricultural Research Service, Denver, Colorado:
R. T. Clark, regional coordinaton, and J. S. Brinks
- IV. Nature and extent of work done this year:

Due to the absence of the project leader on sabbatical leave during 1961-1962, no 1962 report was submitted. However, the work proceeded according to plan.

During the current year the experimental work has been completed and two scientific manuscripts are nearing completion.
- V. Summary of progress and conclusions to date:

The Hereford-Angus trials showed hybrid vigor (or, perhaps more appropriately stated, hybrid advantage) for live animal performance but not for meat quality.

In the Hereford-Charbray experiment, hybrid advantage was not found, either for live animal performance or meat quality.
- VI. Application of findings:

The results of these experiments along with similar ones now being conducted throughout the U.S.A. should afford the industry a sound basis for evaluating the advantages of crossbreeding in beef production.
- VII. Work planned for future:

Project completed.
- VIII. Publications:

Carroll, F. D. 1963. Growth and carcass comparisons of Charbray, Herefords, and Charbray-Hereford crossbreds. Animal Husbandry Department and Agricultural Extension Service, University of California. Beef Cattle Day 1963:8. Mimeog. Rpt.

Rollins, W. C. 1963. Growth and carcass comparisons of Angus, Herefords, and Angus-Hereford crossbreds. Animal Husbandry Department and Agricultural Extension Service, University of California. Beef Cattle Day. 1963:6. Mimeog. Rpt.

Sharrah, Nancy. 1963. Taste panel comparisons of Angus, Herefords, and Angus-Hereford crossbreds and of Charbray, Herefords, and Charbray-Hereford crossbreds. Animal Husbandry Department and Agricultural Extension Service, University of California. Beef Cattle Day. 1963:10. Mimeog. Rpt.

IX. Project summary:

All stock has been disposed of.

COLORADO STATE UNIVERSITY

- I. Station: Colorado Agricultural Experiment Station, Fort Collins, Colorado
- II. Title of project: R & M 26. Study of selection inbreeding and the crossing of inbred lines within the Hereford breed.
- III. Personnel:
 - Experiment Station:
 - H. H. Stonaker (on sabbatical leave, September 1, 1962 - September 1, 1963), Kent Riddle, G. O. Harwin, J. A. Marchello, J. B. Armstrong
 - U. S. Department of Agriculture, Beef Cattle Research Branch, Animal Husbandry Research Division, Agricultural Research Service, Denver, Colorado:
 - R. T. Clark, Coordinator, and J. S. Brinks
- IV. Nature and extent of work done this year:
 1. Heritability of characteristics of the mammary system of Hereford cows

This study was prompted by observations that certain of the inbred lines of cattle characteristically seemed to show a higher incidence of udder trouble and calves required assistance in nursing. This was particularly evident in the case of the Brae Arden line.

An experiment was designed to measure the effects of age, inbreeding, sire and the interaction between age and inbreeding on the udder and teat conformation of cattle at the station. Measurements included the following:

- (a) Distance from ground to floor of udder
- (b) Distance between teats
- (c) Circumference of teats
- (d) Length of teats
- (e) Udder length and width

Measurements were recorded during the spring calving season of 1961 on 130 inbred and linecross Hereford cows. These measurements were repeated in 1962 on all the 2-year and 3-year-old cows.

The method of least squares was used to estimate parameters. Heritability estimates were obtained from paternal half-sib correlations divided by the average relationship among half-sibs within a sire group.

Summary of results:

- (1) Age, inbreeding, and age $\times$ inbreeding interactions had very little effect on most of the udder traits.
- (2) High heritabilities were obtained for most traits in 1961, however, the repeatability of the udder measurements was low in the case of cows measured in 1961 as 2-year-olds and again in 1963 as 3-year-olds.

- (3) There is evidence that traits such as circumference and length of teat, distance between teats, and distance between udder attachments can be improved by selective breeding. Due to the rather limited number of observations, however, caution is necessary in interpreting the results of this study and further investigation is warranted.

Note: Internal pelvic measurements have been taken on all first calf heifers and their relationship to calving difficulty will be investigated.

Table 1.--Heritability estimates of udder measurements in Hereford cows

	1961 data	1962 data
Distance between ground to floor of udder	-.37	-
Distance between front teats	1.64	0.57
Distance between back teats	0.90	0.97
Distance between right front to back	1.16	0.25
Distance between left front to back	1.18	0.33
Circumference of right front teats	0.71	0.28
Circumference of right back teats	0.77	-.19
Circumference of left front teats	1.05	0.40
Circumference of left back teats	0.61	1.06
Length of right front teats	0.48	0.22
Length of right back teats	0.93	0.42
Length of left front teats	0.52	0.08
Length of left back teats	0.99	0.02
Distance from front to back of udder	0.54	0.61
Distance from right to left of udder	0.47	-

2. Synchronizing beef heifers

Attempts to synchronize the oestrus periods of beef heifers initiated during the 1961 breeding season were repeated using the same progesterone compound (Provera) furnished by Upjohn and Company. Provera was fed to 65 cows 2 years and older and 8 yearling heifers at the rate of 180 mg. per day. Provera was fed with 4 lb. of grain once daily or twice daily with 2-1/2 lb.

Conception rates during the induced oestrus were again of a low order and approximated the 30% conception rates obtained in 1961. The results showed that approximately 90% of all provera cows will come into their second heat within 7 days, and 100% within 10 days. The results are summarized in table 2.

Provera is currently very costly and remains in the research phase at this stage.

Table 2.--Results of Provera trial - 1962

<u>Cows, 2 years and older</u>			<u>Provera fed,</u> <u>(June 5 - June 22)</u>	
<u>Controls</u>			<u>Bred artificially then</u>	
<u>Bred naturally, (June 3, 1962)</u>			<u>natural service</u>	
Number observed	169		65	
Not bred	14	8.3%	6	9.2%
Bred 90 days and under	9	5.3%	13	20.0%
Bred 90-120 days	23	13.6%	28	43.1%
Bred 120 days and over	123	72.8%	18	27.7%
Total bred	155	91.7%	59	90.8%

<u>Yearling heifers</u>			<u>Provera fed</u> <u>(June 5-June 22, 1962)</u>	
<u>Controls</u>			<u>Bred artificially then</u>	
<u>Bred naturally (June 25)</u>			<u>natural service</u>	
Number observed	18		8	
Bred 90 days and under	7	38.9%	1	12.5%
Bred 90 days and over	8	44.4%	6	75.0%
Not bred	3	16.7%	1	12.5%
Total bred	15	83.3%	7	87.5%

Conception rates during the induced oestrus were again of a low order and approximated the 30% conception.

3. The effect of inbreeding and environmental factors on the weaning weight and postweaning growth of range Hereford cattle.

This study was initiated to determine the effects of inbreeding and certain environmental and genetic factors on the weaning weight and postweaning growth of range Hereford cattle. The data comprised weaning weight records on 878 heifer calves and 830 bull calves during the period 1946-1962. Yearling data were available on 506 heifers while 2-1/2- and 3-1/2-year weights were available on 403 and 306 Hereford cows, respectively.

The study consisted of three parts, namely: Part I. in which the analysis did not include assessment of all variables, but the size of some of the first order interactions between year, sex, age of dam, and mating system was investigated. This phase also included a preliminary investigation of the effects of inbreeding on weaning weight. Parts II and III are concerned with the assessment of the effect of inbreeding and environmental factors on the weaning weight of range Hereford calves and the postweaning growth of range Hereford females, respectively.

Part I.

In view of a significant age of calf $\times$ year interaction the data were adjusted to a standard age using the calf's own individual daily gain during the last 60 days of the suckling period. Interactions were investigated simultaneously using two procedures:

- (1) Sampling technique - The data were selected in order to obtain equal subclass numbers by randomly reducing the number of animals in all subclasses to the size of the minimum subclass.
- (2) Least squares procedure - All interactions were included in a least squares model. (124 $\times$ 124 matrix). The IBM 7090 computer was used. Both procedures gave very similar results and the study showed the following interactions to be statistically significant:
 - (a) Year $\times$ age of calf
 - (b) Year $\times$ age of dam
 - (c) Sex $\times$ age of dam
 - (d) Sex $\times$ mating system

All these interactions appear to have a logical biological basis and deserve consideration in developing an appropriate model to obtain unbiased estimates of inbreeding and environmental effects influencing weaning weight.

Although the sex $\times$ year interaction was not significant the estimates of the constants indicate a rather definite trend for the difference between heifer and bull calves to be more pronounced in favorable years as reflected by the year constants. The trend is remarkably consistent and lends support to similar observations by Pahnish et al. (1961).

The year $\times$ mating system interaction was not significant but the constants derived should reflect the general response of inbred and linecross cattle to the effect of year. Since inbred animals are generally considered to be more susceptible to adverse environmental conditions, the difference between the weaning weight of inbreds and linecrosses would be expected to be greater during unfavorable years. Although there was some evidence to support this hypothesis, it was too inconsistent to be conclusive and it is possible that the crosslines may have a greater growth potential than inbreds and be held back more in unfavorable years.

The mating system $\times$ age of dam interaction was significant but the constants indicate that the difference in production between 2-year-old and mature cows tends to be more pronounced in bull calves and in the case of inbred calves. It would seem reasonable to conclude that the greater age of dam effect in the case of inbred calves is an expression of the increased susceptibility to environmental and nutritional conditions normally associated with inbred animals. A significant sex $\times$ age of dam interaction was evident, the greater age of dam effect in bull calves is undoubtedly due to the greater growth potential of the bull calves.

The significant sex $\times$ mating system interaction substantiates the earlier observation of homogametic heterosis in the same herd reported by Stonaker (1962). It is apparent from the estimates of the constants that the expression of heterosis is associated with sex, having greater expression in heifer calves than bull calves. The constants indicate that the average superiority of linecrosses over inbred calves (i.e., heterosis) to be of the magnitude of 36 lb. when both sexes are pooled. The amount of heterosis is, however, of the order of 42 lb. for heifer calves and only 30 lb. for bull calves. Although the magnitude of the differential sex response to heterosis is less than that observed by Stonaker (1962) it does substantiate these earlier observations.

In an earlier analysis on the same herd, Landblom (1954), using an approximate test of interactions, tested the three two-factor interactions involving sex, year, and age of dam and found only the sex $\times$ age of dam interaction to be significant. This interaction is of considerable biological interest and the solution factors indicate that the differential sex response to age of dam effect is largely evident in the case of the 2-year-old and mature cows. In the case of bull calves, the constant for mature dams is approximately 13 lb. greater than the constant for 2-year-old dams, while in the case of the heifer calves, the reverse trend is evident. The weaning weight of bull calves appears to be more adversely affected by younger cows than is the weaning weight of heifer calves. This could be attributed to the greater growth potential of bull calves tending to make them more susceptible to adverse environmental conditions.

The relative importance of the year $\times$ age of dam interaction is not readily apparent although the magnitude of the constants suggests that this is a very real effect. There appears to be a definite trend for the production of young cows to be more adversely affected than mature cows in poor years. The superiority of weaning weights of calves from mature dams versus 2-year dams is decidedly more marked in unfavorable years than in favorable years. The distinction between favorable and unfavorable years was based on the magnitude of the year constants. Since younger and older cows would be expected to be more susceptible to adverse climatic and nutritional conditions than mature cows, the existence of the $(YA)_{ij}$ interaction is entirely reasonable.

Preliminary investigation of the significance of the higher powers of F_c and F_d were tested in a multiple regression analysis. The analysis was performed on each sex separately on a within year and age of dam subclass basis. The results indicated that inbreeding effects are probably curvilinear in these data and a differential response to inbreeding was evident in the two sexes. (See figs. 1 and 2).

Part II.

On the basis of the results of the preliminary analyses, a series of models were designed to investigate inbreeding and environmental effects on weaning weight. The two sexes were treated separately and the basic model included the effects of year, age of dam, line/mating

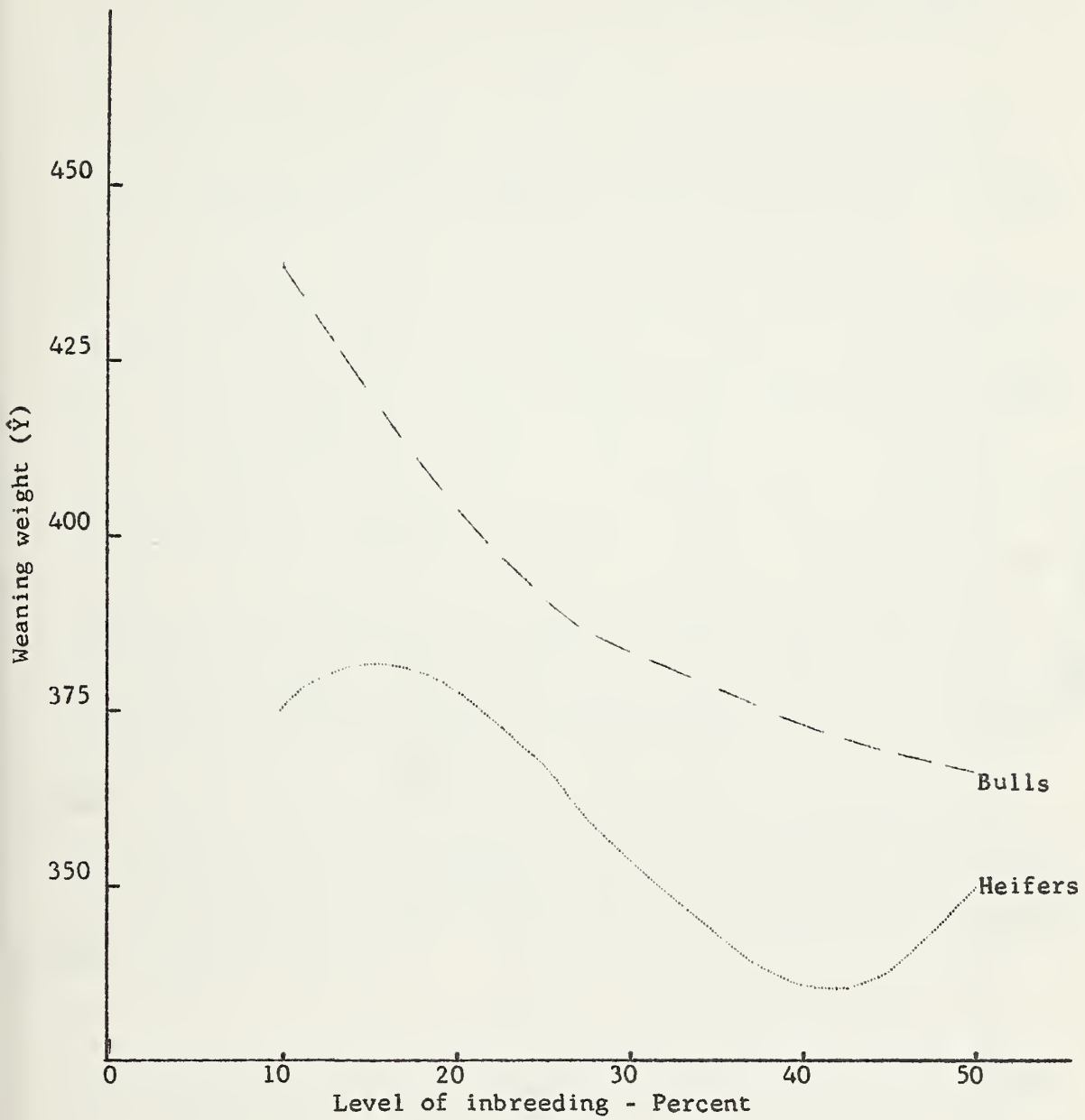


Figure 1.--Effect of inbreeding of calf on weaning weight (inbreeding of dam held constant)

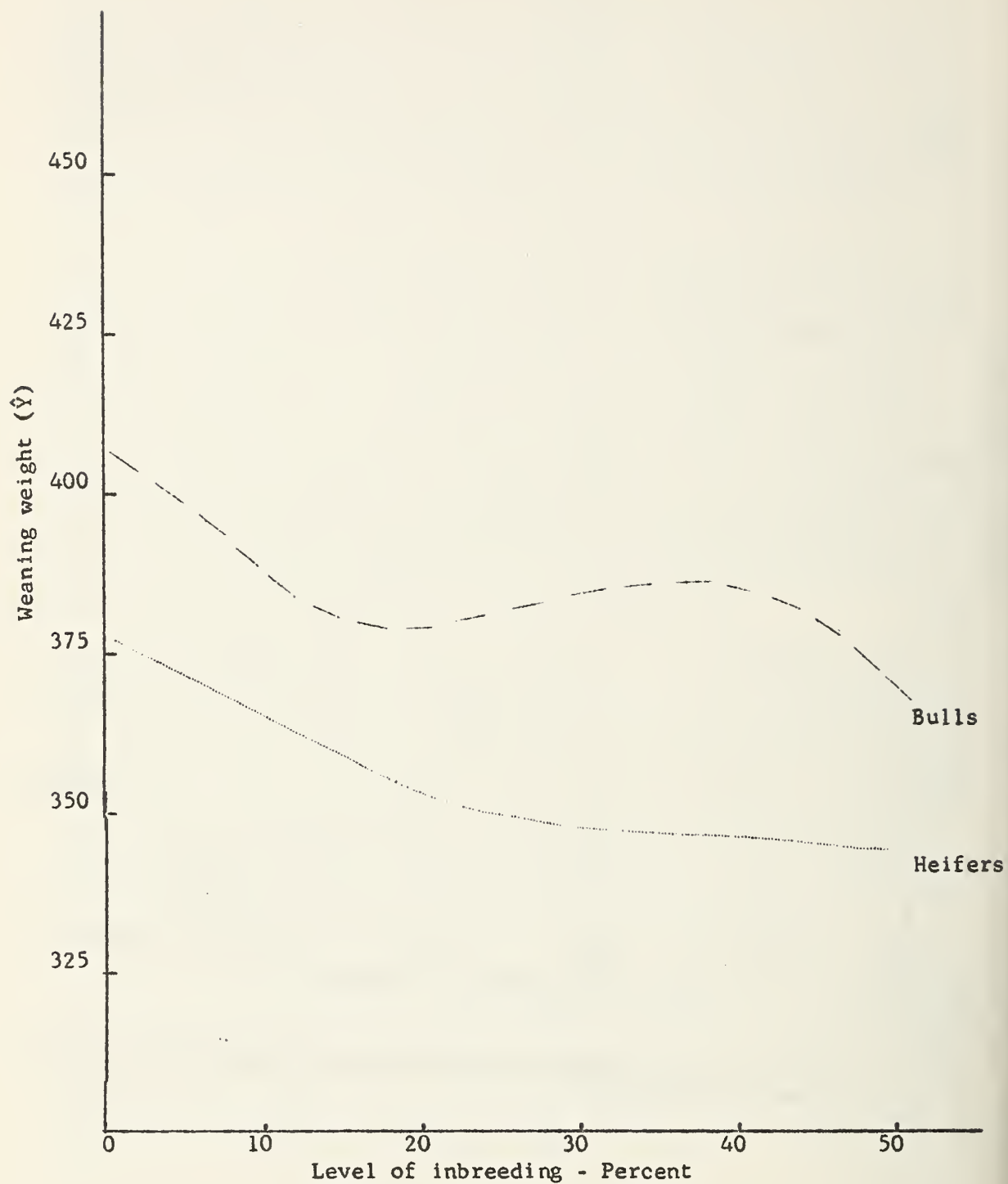


Figure 2.--Effect of inbreeding of dam on weaning weight - (inbreeding of calf held constant)

system, year $\times$ age of dam, age of calf, and the regressions for F_c and F_d to the cubic power. The inclusion of the line/mating system category enabled estimates of inbreeding effect on a polled within line basis and permitted appraisal of the average effect of mating system and general combining ability.

A substantial age of dam effect was evident and 2-year-old cows weaned calves that were approximately 45 lb. higher than calves from mature cows. Very little decline in production was evident for cows 10 years and older. The estimates of the line/mating system constants indicated substantially greater heterosis in heifer calves.

The line/mating system constants obtained from the basic model appeared to be irregular in the case of the bull calves. This irregularity appeared to result from the nature of the polynomial curve for inbreeding of calf effect which forced the intercept through a point above the linecrosses when the curve was extrapolated back to the Y intercept. This caused the constants for the inbred bulls to be of a generally higher order than the constants for the linecrosses. This was in marked contrast to the situation in the heifer calves. When only the linear regression coefficients were considered in the model, this irregularity was no longer evident.

In general the magnitude of the decline in weaning weight with inbreeding was of a lower order than reported by most investigators. The linear estimates of the effects of inbreeding of calf and dam were $-.23$ and $-.76$, respectively, for heifers and $-.41$ and $-.71$, respectively, for bulls. It is evident that inbreeding of dam had a greater effect on weaning weight than inbreeding of calf per se.

The effect of inbreeding was further investigated by categorizing inbreeding into 5% increments and treating it as a discrete variable. The constants obtained, confirmed the earlier analysis and there was further evidence of a curvilinear response to inbreeding. The constants were, however, of an erratic nature and were considered unsuitable for adjustment purposes.

Part III.

The following were the salient results of the study of the effect of inbreeding and environmental factors on postweaning traits in range Hereford females.

- (1) Both year and line/mating system effects were highly significant for all the postweaning traits studied. A substantial effect of production stage (i.e., dry or nursing) was evident in the case of 2-1/2 and 3-1/2 year cow weights.
- (2) Age of dam continued to have a substantial effect on yearling weights although the effect was not significant. No appreciable effect of age of dam was evident in the case of 2-1/2-year weights and the effect was still less on 3-1/2-year weights.

- (3) Some compensation in postweaning growth for the detrimental effect of age and inbreeding of dam was evident from the study of the yearling gain of heifers.
- (4) The amount of heterosis was 6% for yearling and 3-1/2-year weight but no heterosis was evident for yearling gain and 2-1/2-year weights and a slight negative trend was evident.
- (5) Inbreeding effect was not significant for any of the postweaning traits studied, but the results indicated a fairly substantial effect of inbreeding of calf on yearling traits. The effect of inbreeding appeared to diminish with increasing age up to 3-1/2 years.
- (6) The study yielded further evidence of a curvilinear response to inbreeding in these data.

V. Future research:

1. Trends toward greater divergence in performance of inbreds and hybrids and the increased interest of commercial breeders in high performance bulls, make the incorporation of progeny tests of performance selected linecross and inbred bulls a logical addition to the program.

It is contemplated that for at least three years two high indexing linecross bulls and high indexing inbred bulls of the same lines would be mated to unrelated linecrosses. The second part of linecross bulls are being used in the current breeding season.

2. It is contemplated that some of the better, longer established, single sire lines at this point may be enlarged to two sire lines with the most promising young bulls each year tested against the principal herd sire of the line. This would seem to protect the line to a degree against random drift.
3. An investigation is underway to estimate the amounts of selection pressure actually exerted and the genetic trends in the herd. Repeat matings will be the basis for at least part of this estimation.
4. Much needed information on carcass characteristics in the various lines will be available from detailed carcass studies on heifer calves. The first group of heifers from seven of the major lines are currently on feed.

VI. Publications:

Colorado State University, Agricultural Experiment Station. 1963. Beef Cattle Improvement Day and Auction. General Series 789.

Stonaker, H. H. 1963. A genetic hypothesis for sex-mating system interactions in growth of cattle and poultry. J. Anim. Sci. 22(2):320-325.

PROJECT SUMMARY

Cattle Inventory

Purebred

Colorado Agricultural Experiment Station

Breed	Hereford					
Line	Bonanza	Brae Arden	Colorado	Don	Monarch	Prospector
Bulls (12 mos. or over)	1 + 5	4 + 7	1 + 1	1 + 0	1 + 4	2 + 5
Cows (2 yrs. or over)	15	42	9	25	18	27
Heifers, yearlings	5	11	2	4	7	5
Bull calves*						
Heifer calves*						
Percentage used for breeding project	100	100	100	100	100	100
Estimated cash value						

Breed	Hereford				
Line	Real Prince	Rover	Royal	San Juan	Tarrington
Bulls (12 mos. or over)	1 + 0	0	2	2 + 8	1 + 3
Cows (2 yrs. or over)	9	9	24	25	32
Heifers, yearlings	2	0	8	14	3
Bull calves*					
Heifer calves*					
Percentage used for breeding project	100	100	100	100	100
Estimated cash value					

Breed	H&A-Sh.			
Line	Crossbred	Control	Model Domino	on Lease
Bulls (12 mos. or over)	0 + 0	1 + 3	0 + 0	4
Cows (2 yrs. or over)	9	18	1	-
Yearling heifers	0	2	0	-
Bull calves*				
Heifer calves*				
Percentage used for breeding project	100	100	100	100
Estimated cash value				

*Since calving is still in progress, details of the 1963 calf crop are not yet available - approximately 200 calves have been born to date.

Colorado Agricultural Experiment Station
Cow Production Data (By line of dam's sire)

1962 calving

Breed	Hereford					
	Bonanza		Brae Arden		Colorado	
Line	Inbred Linecross		Inbred Linecross		Inbred Linecross	
Cows bred to calve as 2-yr-olds	3	3	3	4	-	-
Calves born from 2-yr-olds						
Alive	1	2	2	3	-	-
Dead	0	0	0	0	-	-
Cows bred to calve at 3 yrs and up	5	9	19	24	6	3
Calves born from 3-yr.-olds and up						
Alive	5	6	10	21	4	2
Dead	0	0	2	1	0	0
All calves born						
Alive	5	8	12	24	4	2
Dead	0	0	2	1	0	0
Total	6	8	14	25	4	2
Calves weaned	6	8	12	24	4	2
Percent calf crop						
Birth	75	75	64	89	67	67
Weaning	75	75	55	86	67	67

Calf Data (By line of calf's sire)

	Bulls		Heifers		Bulls		Heifers		Bulls		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.
INBREDS												
Weaning age	4	192	2	176	6	198	6	202	2	214	2	219
Weaning weight		386		313		326		303		423		382
Adj. weaning wt. 200 days		527		531		473		453		516		492
Weaning score:												
Conf.		4.5		4.5		4.3		4.3		4.8		4.7
Inbreeding of calf		.44		.50		.45		.42		.35		.36
Inbreeding of dam		.33		.38		.42		.36		.27		.42
LINECROSSES												
Weaning age	5	187	3	192	10	182	14	194			2	212
Weaning weight		340		358		331		354				480
Adj. weaning wt. 200 days		373		409		382		409				495
Weaning score:												
Conf.		4.5		4.5		4.3		4.6				5.8

Colorado Agricultural Experiment Station

Cow Production Data (By line of dam's sire)

1962 calving

Breed	Hereford		H. × A.Sh.
Line	Don Inbred Linecross	Control	Crossbreds
Cows bred to calve as 2-yr-olds	5 2	4	-
Calves born from 2-yr-olds			
Alive	2 0	2	-
Dead	3 1	0	-
Cows bred to calve at 3 yrs. and up	6 10	14	9
Calves born from 3-yr-olds and up			
Alive	5 9	11	9
Dead	0 0	1	0
All calves born			
Alive	7 9	13	9
Dead	3 1	1	0
Total	10 10	14	9
Calves weaned	7 9	13	9
Percent calf crop			
Birth	91 83	78	100
Weaning	64 75	72	100

Calf Data (By line of calf's sire)

	Bulls		Heifers		Bulls		Heifers		Bulls		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.
INBREDS												
Weaning age	2	207	5	174								
Weaning weight		368		283								
Adj. weaning wt. 200 days		456		480								
Weaning score:												
Conf.		4.3		3.8								
Inbreed. of calf		.34		.43								
Inbreed. of dam		.28		.31								
LINECROSSES												
Weaning age	7	199	2	208	7	195	6	192	5	207	4	201
Weaning weight		374		418		387		343		550		496
Adj. weaning wt. 200 days		390		448		416		395		545		521
Weaning score:												
Conf.		4.8		5.0		4.4		4.9		6.0		6.0

Colorado Agricultural Experiment Station
Cow Production Data (By line of dam's sire) 1962 calving

Breed	Hereford					
Line	Model Domino Inbred Linecross	Monarch Inbred Linecross		Prospector Inbred Linecross		
Cows bred to calve as 2-yr-olds		3	5	3	4	
Calves born from 2-yr-olds						
Alive		1	1	1	2	
Dead		1	1	0	0	
Cows bred to calve at 3yrs. and up	1	8	9	11	7	
Calves born from 3-yr-olds and up						
Alive	0	7	5	7	7	
Dead	1	0	2	3	0	
All calves born						
Alive	0	8	6	8	9	
Dead	1	1	3	3	0	
Total		9	9	11	9	
Calves weaned	0	8	6	8	9	
Percent calf crop						
Birth		82	64	79	82	
Weaning		73	43	57	82	

Calf Data (By line of calf's sire)

	Bulls		Heifers		Bulls		Heifers		Bulls		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.
INBREDS												
Weaning age					5	202	4	178	4	195	4	210
Weaning weight						379		295		451		423
Adj. weaning wt. 200 days						477		464		547		523
Weaning score:												
Conf.						4.9		4.1		4.4		4.6
Inbreed. of calf						.32		.35		.28		.31
Inbreed. of dam						.26		.29		.20		.25
LINECROSSES												
Weaning age					6	192	2	213	5	196	4	195
Weaning weight						401		362		375		361
Adj. weaning wt. 200 days						432		380		409		411
Weaning score:												
Conf.						4.5		4.3		4.4		4.4

Colorado Agricultural Experiment Station
Cow Production Data (By line of dam's sire)

1962 calving

Breed	Hereford			
Line	Real Prince Inbred Linecross	Rover Inbred Linecross	Royal Inbred Linecross	
Cows bred to calve as 2-yr-olds	5	4	3	4
Calves born from 2-yr-olds				
Alive	1	2	2	3
Dead	0	1	0	0
Cows bred to calve at 3 yrs. and up	6	5	8	10
Calves born from 3-yr-olds and up				
Alive	3	4	4	8
Dead	1	0	1	1
All calves born				
Alive	4	6	6	11
Dead	1	1	1	1
Total	5	7	7	12
Calves weaned	4	6	6	11
Percent calf crop				
Birth	45	78	64	86
Weaning	36	67	55	79

Calf Data (By line of calf's sire)

	Bulls		Heifers		Bulls		Heifers		Bulls		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.
INBREDS												
Weaning age	2	191	2	211					3	178	3	153
Weaning weight		342		342						297		270
Adj. weaning wt. 200 days		499		433						475		518
Weaning score:												
Conf.		4.5		4.3						3.8		3.8
Inbreed. of calf		.45		.30						.46		.47
Inbreed. of dam		.26		.19						.43		.36
LINECROSSES												
Weaning age					3	174	3	194	5	203	6	187
Weaning weight						330		347		443		358
Adj. weaning wt. 200 days						401		405		459		425
Weaning score:												
Conf.						4.3		4.6		4.9		4.8

Colorado Agricultural Experiment Station

Cow Production Data (By line of dam's sire) 1962 calving

Breed	Hereford		
Line	San Juan Inbred Linecross		Tarrington Inbred Linecross La Plata Inbred Linecross
Cows bred to calve as 2-yr-olds	3	2	9
Calves born from 2-yr-olds			
Alive	0	1	6
Dead	0	1	0
Cows bred to calve at 3 yrs. and up	14	10	12
Calves born from 3-yr.-olds and up			
Alive	9	7	10
Dead	1	0	1
All calves born			
Alive	9	8	16
Dead	1	1	1
Total	10	9	17
Calves weaned	9	8	16
Percent calf crop			
Birth	59	75	81
Weaning	53	67	76

Calf Data (By line of calf's sire)

	Bulls		Heifers		Bulls		Heifers		Bulls		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.
INBREDS												
Weaning age	7	204	2	203								
Weaning weight		363		393								
Adj. weaning wt. 200 days		470		511								
Weaning score:												
Conf.		4.4		4.8								
Inbreed. of calf		.36		.29								
Inbreed. of dam		.28		.24								
LINECROSSES												
Weaning age	5	184	4	184	7	183	9	179				
Weaning weight		350		333		389		331				
Adj. weaning wt. 200 days		379		405		444		415				
Weaning score:												
Conf.		4.7		4.8		4.8		4.5				

Colorado Agricultural Experiment Station

Feedlot Performance

Date: May 11, 1963

Breed	Hereford	Angus	Crossbred	Charolais
Sex	Bulls	-	Bulls	Bull
Number on test	96	-	3	1
Average:				
Age on test	-	-	-	-
Initial weight	437	-	531	453
Initial score:				
Cond.	-	-	-	-
Conf.	-	-	-	-
Days on test	140	-	140	140
Average gain per head	347	-	406	430
Average daily gain	2.49	-	2.90	3.07
Efficiency of				
feed utilization				
lbs. TDN/100 lbs. gain	6.58	-	5.84	5.29
Final weight	784	-	938	883
Final score:				
Conf.	4.8	-	5.5	5.0

A further 100 yearling bulls have been wintered on a growing ration since Dec. 24, 1962 and will be placed on a 140-day gain test on June 1, 1963.

Young Animals on Feed

Purebred

Date: May 11, 1963

	Hereford		Angus		Shorthorn	
	Number individu- ally fed	Number group fed	Number individu- ally fed	Number group fed	Number individu- ally fed	Number group fed
Bulls	96	98	1	-	-	-
Heifers	-	-	-	-	-	-
Steers	-	-	-	-	-	-

Grades - Crossbred (H x Angus - Shorthorn)

Bulls	3	2
Heifers	-	-
Steers	-	-

UNIVERSITY OF HAWAII

- I. Station: Hawaii Agricultural Experiment Station, Honolulu, Hawaii
- II. Project title: The estimation of genetic and phenotypic parameters in populations of beef cattle in Hawaii and their use in selection programs
- III. Personnel:

Experiment Station:

Estel H. Cobb, Oliver Wayman, Isaac Iwanaga, Kiyochi Morita, and Artemio Ovejera (also manager of the Hawaiian Ranch Company and its stock handling personnel)

U. S. Department of Agriculture, Agricultural Research Service, Denver, Colorado:

R. T. Clark, Coordinator, and J. S. Brinks

- IV. and V. Nature and extent of work done this year and summary of progress:

Weights and conformation scores at weaning, 12 months, and 20 months of age were obtained as planned. The progeny testing of steers from various sires for rate of gain and carcass characteristics has continued.

All of the 1962 calves were weighed at approximately 4-1/2, 6-1/2, and 8 months of age to obtain information on the preweaning growth. Growth from birth to weaning at 8 months of age was definitely curvilinear. The average growth rate from a constant birth weight of 70 pounds to 137 days of age was 2.1 pounds per day. The average daily gain from 138 to 196 days of age was 1.4 pounds per day, and from 196 to 251 days of age was 0.6 pounds per day. Part of this change in growth rate can be attributed to the change in feed conditions. In addition, some of the decline is due probably to the fact that the decrease in milk supply of the mother is decreasing at a faster rate than the ability of the calf to utilize other sources of feeds is increasing. This situation would be especially critical in situations similar to Hawaii where we have a rather high moisture content to our forages.

Preliminary studies on the relationships between rate of gain on test and certain carcass characteristics have continued. Some of the more interesting results are presented in the following.

Records on 1306 grade Hereford calves sired by 28 bulls on two ranches from 1954 to 1960 were analyzed to determine the effects of sire, year, age of dam, sex, ranch, and age of calf on weaning weight, preweaning gain, and conformation score. The effects of all these sources of variation were highly significant for all three traits. The average 8-month weaning weight, average daily gain, and conformation score were 448 lb., 1.55 lb., and 4.3 (scale of 1 to 9, with 9 maximum),

respectively. Bulls were 27.5 lb. or 6% heavier at weaning and gained 0.11 lb. per day more, or 8% faster from birth to weaning than heifers. Heifers graded significantly higher than bulls at weaning. Calves from 3-, 4-, 5-, and 6-year-old dams were 31, 21, 10, and 5 lb. lighter, respectively, than calves from dams 7-9 years of age. Age of dam had a similar effect on preweaning gain and conformation score at weaning. The regressions of weaning weight, preweaning gain, and conformation score on age at weaning were 0.71 lb., -.004 lb., and 0.01, respectively. Heritabilities for weaning weight, preweaning gain, and conformation score were 0.24, 0.26, and 0.36, respectively, as computed from the paternal half-sib correlations.

The phenotypic correlations between weaning weight and preweaning gain, between weaning weight and conformation score, and between preweaning gain and conformation score were 0.85, 0.63, and 0.62, respectively. The corresponding genetic correlations were 0.82, 0.45, and 0.38, respectively, and the corresponding environmental correlations were 0.87, 0.72, and 0.74, respectively.

A selection index using weaning weight and conformation score was developed. The two traits were given economic values so that one standard deviation of weaning weight was equal in value to one standard deviation of conformation score. The resulting selection index was $I = 0.1X_1 + 29.0X_2$ where I = index; 0.1 and 29.0 are constants;

X_1 and X_2 are the adjusted phenotypic values of weaning weight and conformation score after adjustments have been made for sex of calf, age of dam, and age of calf.

Forty Hereford steers were used to study the relationship between yield of trimmed retail cuts and certain carcass and live animal characteristics. The steers were randomly divided into two groups of 20 steers each. One group was fattened on a high concentrate ration in the feedlot and the other group was fattened on grass and received a molasses-soybean supplement. The steers were on test from 650 to 1050 lb. liveweight. The average slaughter weight was 1049 lb. Product moment correlations were computed on a within-group basis. Yield of trimmed retail cuts was highly correlated with specific gravity of the whole carcass (0.74) and percent waste from the carcass (-.89). Low and nonsignificant correlations were found between yield of trimmed retail cuts and averagedaily gain on test (0.20), carcass grade (-.14), rib-eye area (-.02), dressing percentage based on empty body weight (-.22), marbling score (-.20), and fat thickness over the rib-eye (-.22). Yield of trimmed retail cuts was significantly correlated with slaughter grade (-.33), ether extract of the rib-eye muscle (-.36), yield grade (-.33), and carcass weight (-.39). The multiple correlation coefficient between yield of trimmed retail cuts and carcass weight, fat thickness over the rib-eye, and rib-eye area was 0.41. In this study, information on carcass weight, fat thickness over the rib-eye, and rib-eye area had a low predictive value for predicting yield of trimmed retail cuts.

Table 1.--Correlations among average daily gain and carcass traits^a

	Slaughter grade 2	Percent retail cuts 3	Carcass grade 4	Rib-eye area 5	Dressing percent 6	Percent waste 7	Marbling score 8	Specific gravity 9	Fat thick- ness over rib eye 10	Ether extract 11	Yield grade 12	Carcass weight 13
Av. daily gain (1)	0.06	0.20	-.13	-.27	-.42	-.28	-.11	0.28	0.24	-.15	0.19	-.28
(2)		-.33	.09	.48	.09	.37	.11	-.45	.13	.26	-.01	.29
(3)			-.14	-.02	-.22	-.89	-.20	.74	-.22	-.36	-.33	-.39
(4)				.05	-.18	.29	.53	-.02	-.14	.51	.20	.09
(5)					.16	.13	-.05	-.23	-.27	.24	-.63	.30
(6)						.22	-.25	-.15	.12	.11	-.35	.54
(7)							.27	-.85	.25	.43	.21	.50
(8)								-.19	-.14	.44	.08	-.03
(9)									.04	-.45	-.15	-.46
(10)										-.13	.40	.28
(11)											-.08	.29
(12)												-.25

^aComputed from pooled sum of squares and crossproducts within treatment. df = 36.

VI. Application of findings:

Interest still runs high with regard to the use of record of performance in Hawaii.

VII. Work planned for the future:

The collection of conformation scores and liveweights at 8, 12, and 20 months will continue.

The analysis of the data collected from 1955 to date will continue with emphasis on heritability estimates of weights and conformation scores at 12 and 20 months of age. In addition, the genetic-phenotypic and environmental correlations among the weights and conformation scores at 8, 12, and 20 months of age will be computed.

A beef cattle station at Waimea on the island of Hawaii is in the process of being established. Research to study the importance of genetic-environmental interactions in beef cattle breeding is being considered for implementation at the new station. Some attention will be given to beef breeds other than Herefords.

VIII. Publications:

Iwanaga, Isaac I., and Estel H. Cobb. 1963. Relationship between yield of trimmed retail cuts and certain carcass characteristics of beef cattle. Amer. Soc. Anim. Prod. West. Sect. Proc. 14.

Mahmud, Anuwar. 1963. The estimates of heritability of weaning weight, preweaning gain, and conformation score of range beef cattle. M. S. Thesis. University of Hawaii, Honolulu.

Mahmud, Anuwar, and Estel H. Cobb. 1963. Factors affecting weaning weights, preweaning gains, and conformation scores of beef calves in Hawaii. Amer. Soc. Anim. Prod. West. Sect. Proc. 14.

RELATIONSHIPS BETWEEN YIELD OF TRIMMED RETAIL CUTS AND
CERTAIN CARCASS CHARACTERISTICS OF BEEF CATTLE

Isaac I. Iwanaga and Estel H. Cobb

Table 1.--Means of traits

Trait	Treatment 1 feedlot	Treatment 2 pasture lot	Diff.
Weight at end of feeding period, lb.	1037.6	1059.5	-21.9**
Slaughter weight, lb.	994.1	1010.5	-16.4**
Slaughter grade ^a	18.6	17.2	1.4**
Av. daily gain, lb/day	2.23	1.12	1.11**
Chilled carcass weight, lb.	611.1	607.4	3.7
Dressing percent	66.0	65.0	1.0*
Carcass grade score ^a	18.1	16.7	1.4**
Yield grade ^b	3.0	2.7	0.3
Marbling score ^c	5.4	4.6	0.8**
Specific gravity	1.0568	1.0628	-.0060**
Ribeye area, sq. in.	11.0	11.3	-.3
Av. fat thickness over ribeye area, mm.	18.6	13.5	5.1**
Percent trimmed retail cuts	67.1	66.3	0.8
Percent waste	17.2	17.3	-.1
Ether extract, percent ^e	4.1	3.4	0.7*

* P < 0.05

** P < 0.01

^a22 = Low Prime, 21 = High Choice, 20 = Average Choice, 19 = Low Choice, 18 = High Good, 17 = Average Good, etc.

^bUSDA yield grades 1 through 6.

^cUSDA marbling scores, 8 = slightly abundant to 4 = slight.

^dPercent trimmed retail cuts in the round, loin, chuck, and rib including lean trimmings.

^eSample from longissimus dorsi muscle.

Table 2.--Correlations between yield of trimmed retail cuts and various live animal and carcass traits

Traits	Within treatment	Independent of carcass weight
Av. daily gain	0.20	0.10
Slaughter grade score	-.33*	-.25
Chilled carcass weight	-.39*	--
Dressing percent	-.22	-.01
Carcass grade score	-.14	-.11
Yield grade	-.33*	-.48
Marbling score	-.20	-.23
Specific gravity	0.74**	0.69
Ribeye area	-.02	0.11
Av. fat thickness over ribeye area	-.22	-.13
Percent waste	-.89**	-.87
Ether extract	-.36*	-.28

FACTORS AFFECTING WEANING WEIGHTS, PREWEANING GAINS, AND
CONFORMATION SCORES OF BEEF CALVES IN HAWAII

Anuwar Mahmud and Estel H. Cobb

Model:

$$Y_{ijklmn} = u + s_i + d_j + g_k + t_l + r_m + b(X_{ijklmn} - \bar{X}) + e_{ijklmn}$$

Where $i = 1, 2, \dots, 28$

$j = 1, 2, \dots, 8$

$k = 1, 2, \dots, 7$

$l = 1, 2$

$m = 1, 2$

$(X_{ijklmn} - \bar{X})$ = The age of calf expressed as deviation from the population mean. Age at weaning was treated as a continuous variable.

Y_{ijklmn} = the n^{th} observation of the i^{th} sire, from the j^{th} age of dam group, in the k^{th} year, of the l^{th} sex and on the m^{th} ranch.

X_{ijklmn} = the age of the n^{th} calf at weaning of the i^{th} sire, j^{th} age of dam, k^{th} year, l^{th} sex, and m^{th} ranch.

$\bar{X}$ = the mean age in days of all calves at weaning.

b = the partial regression of each weanling trait on age at weaning with sires, age of dams, years, sexes, and ranches held constant.

The s_i, d_j, g_k, t_l, r_m are all constants such that $\sum_i \hat{s}_i = \sum_j \hat{d}_j = \sum_k \hat{g}_k = \sum_l \hat{t}_l = \sum_m \hat{r}_m = 0$.

Table 1.--Averages by ages of dam, years, sexes, and ranches for the weanling traits

Classification	Number of observations	Weaning weight lb.	Preweaning gain lb.	Conformation score
Age of dam in years				
3	270	405	1.35	3.5
4	278	406	1.37	3.8
5	235	424	1.47	3.8
6	158	434	1.51	4.1
7	129	426	1.48	4.0
8	93	422	1.45	4.1
9	46	421	1.40	4.2
10 and older	97	451	1.56	4.4
Years				
1955	70	420	1.47	3.1
1956	168	469	1.77	4.2
1957	204	467	1.64	3.9
1958	210	454	1.64	3.5
1959	273	394	1.27	4.0
1960	193	364	1.17	3.9
1961	188	377	1.16	4.3
Sexes				
Male	613	433	1.49	3.7
Female	693	408	1.38	4.1
Ranches				
Kaalualu	1140	413	1.40	3.8
Kapapala	116	467	1.67	4.7
Overall means	1306	419	1.43	3.9
Standard deviations		81	0.36	1.2
Coefficients of variability		19%	25%	29%

Table 2.--Constants for age of dam, year, sex, ranch, and age of calf at weaning with sire classification absorbed

Classification	Weaning weight	Preweaning gain	Conformation score ^a
Ages of dam in years			
3	-23.5 ± 4.0	-0.093 ± 0.017	-0.39 ± 0.07
4	-13.2 ± 3.9	-0.054 ± 0.016	-0.08 ± 0.06
5	-2.4 ± 4.2	-0.004 ± 0.017	0.05 ± 0.07
6	3.4 ± 4.8	0.017 ± 0.020	0.08 ± 0.08
7	7.9 ± 5.2	0.034 ± 0.022	0.10 ± 0.09
8	7.8 ± 6.0	0.031 ± 0.025	0.19 ± 0.10
9	8.2 ± 1.1	0.022 ± 0.034	0.03 ± 0.14
10 and older	11.8 ± 6.3	0.048 ± 0.007	0.01 ± 0.11
Years			
1955	0.7 ± 22.3	-0.113 ± 0.094	-0.95 ± 0.38
1956	68.0 ± 6.2	0.297 ± 0.026	0.79 ± 0.10
1957	46.0 ± 6.3	0.206 ± 0.026	0.22 ± 0.11
1958	40.9 ± 6.6	0.172 ± 0.028	-0.24 ± 0.11
1959	-16.2 ± 5.6	-0.047 ± 0.023	0.39 ± 0.09
1960	-67.9 ± 7.3	-0.264 ± 0.030	-0.15 ± 0.12
1961	-71.7 ± 8.1	-0.252 ± 0.034	-0.06 ± 0.14
Sexes			
Male	13.8 ± 1.7	0.056 ± 0.007	-0.21 ± 0.03
Female	-13.8 ± 1.7	-0.056 ± 0.007	0.21 ± 0.03
Ranches			
Kaalualu	-31.8 ± 4.7	-0.133 ± 0.020	-0.53 ± 0.08
Kapapala	31.8 ± 4.7	0.133 ± 0.020	0.53 ± 0.08
Age of calf			
	0.7 ± 0.1	-0.004 ± 0.000	0.01 ± 0.00
Overall means			
	447.5	1.547	4.27

^a9 maximum, 1 minimum.

Table 3.--Estimates of heritability of weanling traits

Traits	Estimates
Weaning weight	0.24
Preweaning gain	0.26
Conformation score	0.36

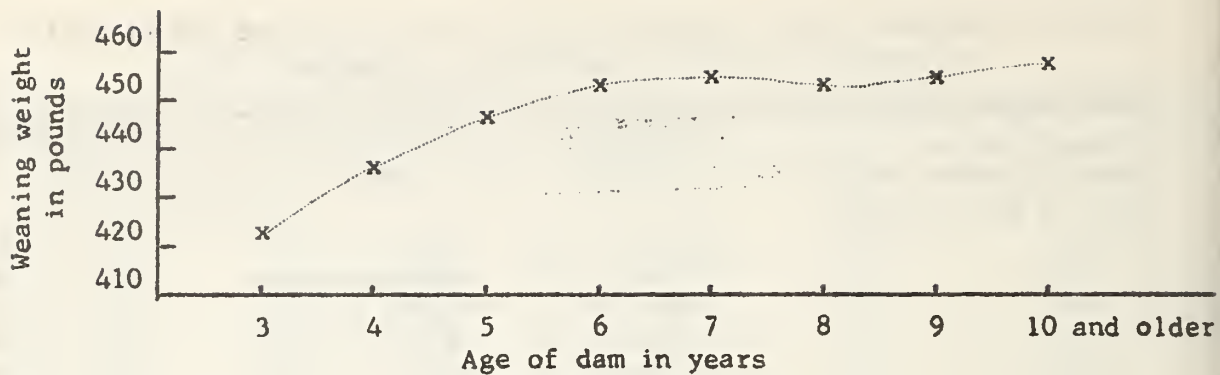


Figure 1.--Influence of age of dam on weaning weight.

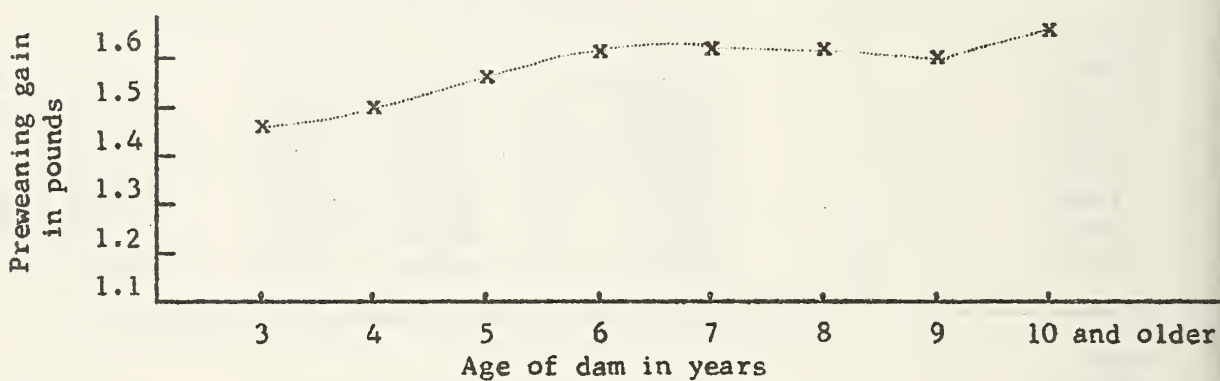


Figure 2.--Influence of age of dam on preweaning gain.

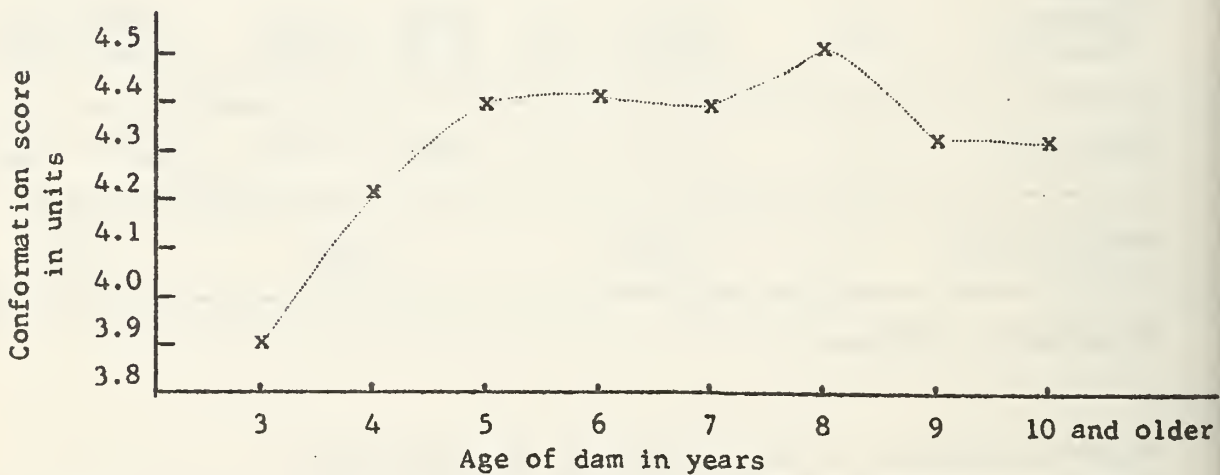


Figure 3.--Influence of age of dam on conformation score.

IX. PROJECT SUMMARY

Cattle Inventory Hawaii Agricultural Experiment Station

Grade

Date: June 1963

Breed	Hereford
Line	Kaalualu and Kapapala
Station	Hawaii
Bulls (12 mos. or over)	114
Cows (2 yrs. or over)	403
Heifers, yearlings	145
Bull calves	165
Heifer calves	173
Percentage used for breeding project	100
Estimated cash value	\$350,000

Cow Production Data

Breed	Hereford
Line	Kaalualu, Kapapala, and Martin
Cows bred to calve at 3 yrs. and up	400
Calves born from 3-yr-olds and up	
Alive	343
Dead	11
Calves weaned	314
Percent calf crop*	
Birth	85.8
Weaning	78.5

*Based on number of cows exposed to the bull and the number of live calves.

	Bulls	Steers	Heifers
Number	147	16	138
Average weaning:			
Age	250.4	245.7	252.0
Weight*	462.9	458.4	432.5
Adj. weight, 240 days	447.2	451.3	415.4
Conformation score**	4.7	4.8	4.9

*Overnight shrink without feed or water.

**Based on grading system where 9 is the highest score and 1 is the lowest.

Land, Physical Facilities, and Equipment Used

Item	Number	Actual cash value	Percentage used for breeding project
Land (acres) Kaalualu	2070	\$ 22,700	100 annual lease value
Corrals, chutes, & scales	1 set	5,000	100
Portable scale	1	650	80
University of Hawaii			
Pasture (acres) irrigated	12.5	12,500	100
Portable scale	1	650	50
Corrals, chutes, scale, and barn	1 set	10,000	90
Meat laboratory	1	80,000	75
Working horse	1	250	80
Irrigation system	1	15,000	60
Profilometer	1	200	100
Leica camera set	1	613	50
Electronic ejaculator	1	544	100
Monroe adding machine	1	238	65
Monroe calculator	1	1,014	100
Friden calculator	1	659	80
IBM electric typewriter	1	270	20
Stenorrete dictating machine	1 set	485	100
Air conditioner	1	230	100
Wiley laboratory mill	1	275	90
RCA refrigerator	1	350	50
Power chain saw	1	160	75
Toledo scale	1	400	75
Miscellaneous equipment		1,791	100
Total value		\$ 153,979	

UNIVERSITY OF IDAHO

- I. Station: Idaho Agricultural Experiment Station
- II. Project Title: The improvement of economically important traits in beef cattle with special emphasis on fertility and carcass quality.
- III. Personnel:
 - Experiment Station:
R. E. Christian, L. E. Orme, T. D. Bell, C. W. Hodgson,
and S. E. Slyter
 - U. S. Department of Agriculture, Beef Cattle Research Branch,
Animal Husbandry Research Division, Agricultural Research Service,
Denver, Colorado:
R. T. Clark, Coordinator, and J. S. Brinks
- IV. and V. Nature and extent of work done this year and summary of progress and conclusions to date:

Eighteen bull calves (12 Hereford, 3 Angus, and 3 Shorthorn) were individually fed for 140 days following weaning to obtain feedlot gain and feed efficiency. The average rate of daily gain for the Herefords was 1.91 pounds, for the Angus 2.03 pounds, and for the Shorthorns 1.73 pounds.

These bull calves were also used in the continuation of the study on semen production in the young beef bull. They were divided into three experimental groups: Group 1 - Attempts at semen collection with the electroejaculator at biweekly intervals. Group 2 - Attempts at semen collection with the artificial vagina at biweekly intervals. Group 3 - Alternate attempts at collection with the electroejaculator and the artificial vagina at biweekly intervals.

Attempts of semen collection were initiated when the bulls were approximately 7 months of age.

Of the 12 bulls in the groups (2 and 3) from which semen collections were attempted with the artificial vagina, only one Hereford bull has produced a satisfactory ejaculate to date. The other bulls in these groups have shown sexual interest in the teaser cow and all except the 3 Shorthorns have mounted and had an erection. Accessory fluid has been collected from all of the Hereford bulls.

Satisfactory semen samples have been collected from all bulls in the electroejaculator groups (1 and 3). The data from the two-year study with the electroejaculator have been combined and are presented in table 1.

Table 1.--Average ages in days at attainment of certain puberty phenomena

Breed	Number of animals	First erection	Collection of first spermatozoa	Collection of first motile spermatozoa	First successful ejaculate ¹
<u>1961</u>					
Hereford	12	303.4	294.6	316.9	341.4
Shorthorn	3	263.7	263.7	279.7	339.0
Angus	3	275.0	291.0	330.3	401.7
Average	18	292.0	288.8	312.9	351.0
<u>1963</u>					
Hereford	8	223.5	289.6	303.6	338.9
Shorthorn	2	219.0	292.0	292.0	323.5
Angus	2	235.0	277.0	286.0	347.0
Average	12	224.7	287.9	298.8	337.7
Average of both studies	30	258.4	288.4	305.8	344.4

¹ Initial progressive motility > 50%; sperm concentration > 100×10^6 /cc.

These data indicate that satisfactory ejaculates can be obtained from the beef bull with the electroejaculator at less than one year of age. There was a difference of 67.3 days in age at first erection between the two years. This may have been due primarily to an increase in the skill of the electroejaculator technician.

The first steer progeny of the Hereford bulls from the University of Idaho here that were leased to cooperating cattlemen for progeny testing are now being fed in the University feedlot. These steers will be slaughtered this summer and carcass information obtained. For the first 196 days of the feeding test, the calves from one ranch have gained approximately 0.1 pound per day faster than those from the other ranch. The differences between sires within ranches were 0.03 and 0.10 pounds per day. Steer calves from four additional ranches will be available this fall.

VI. Application of findings:

Two years' data on semen production in the young beef bull indicate that satisfactory semen samples can be obtained from the beef bull with the electroejaculator at less than one year of age. Erections can be obtained approximately 90 days before successful ejaculations. However, the age at first erection is not an accurate indication of the age at first successful ejaculation ($r = .141$). The information from this study

will be of value to cattlemen who desire to determine the potential fertility of young beef bulls prior to the age they are commonly used for breeding.

The progeny testing phase of the study will indicate to cattlemen the value of the progeny test for carcass characteristics and the value of various predictors of carcass quality and composition.

VII. Work planned for the future:

The study on semen production in the young beef bull will be continued this year with added emphasis on the comparison of the artificial vagina and electroejaculator. The steer calves now on feed will be slaughtered this summer and carcass analysis will be completed. Additional steer calves will be placed on feed this fall from other bull pairs from the University herd.

VIII. Publications:

Christian, R. E., and F. R. Wolf. 1963. Electroejaculation in the young beef bull. Amer. Soc. Anim. Prod. West. Sect. Proc. 14.

PROJECT SUMMARY

Cattle Inventory
Purebred

Idaho Agricultural Experiment Station

June 1, 1963

Breed	Hereford	Angus	Shorthorn	Hereford
Line				Carrier
Station	Main	Main	Main	Main
Bulls (12 mos. or over)	16	7	4	0
Cows (2 yrs. or over)	56	25	24	5
Heifers, yearlings	12	4	4	0
Bull calves	20	10	7	2
Heifer calves	21	6	10	3
Percentage used for breeding project	60	60	60	100
Estimated cash value	45,600	22,400	23,200	2,000

Idaho Agricultural Experiment Station

Cow Production Data

Date: June 1, 1963

Breed	Hereford		Angus		Shorthorn	
Line						
Cows bred to calve as 2-yr. olds	0		0		0	
Calves born from 2-yr. olds						
Alive	0		0		0	
Dead	0		0		0	
Cows bred to calve at 3 yrs. and up	52		20		23	
Calves born from 3-yr. olds and up						
Alive	43		15		18	
Dead	2		4		2	
All calves born						
Alive	43		15		18	
Dead	2		4		2	
Total	45		19		20	
Calves weaned	40		15		18	
Percent calf crop*						
Birth	82.7		75.0		78.3	
Weaning	76.9		75.0		78.3	

	Bulls		Heifers		Bulls		Heifers		Bulls		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.
Average:												
Birth weight	22	69.8	21	66.0	9	70.7	6	63.0	8	67.1	10	59.5
Weaning age		167.5		175.5		161.4		191.0		183.0		165.9
Weaning weight	20	371.8	20	357.0	9	387.8	6	356.7	8	412.5	10	303.5
Adj. weaning wt. - 200 days		430.4		425.7		464.9		405.2		446.2		379.4
Weaning score:												
Conformation	20	11.4	20	11.7	9	11.3	6	11.8	8	12.4	10	11.5

* Calves born or weaned per 100 cows bred.

Idaho Agricultural Experiment Station

Feedlot Performance

June 1, 1963

Breed	Hereford	Shorthorn	Angus
Sex	Bull	Bull	Bull
Number on test	12	3	3
Average:			
Age on test	212.5	224.3	226.3
Initial weight	455.2	486.0	532.3
Initial score			
Conformation	11.6	12.7	13.0
Days on test	141	141	141
Gain			
Total	268.6	244.0	286.0
Average daily gain	1.91	1.73	2.03
Efficiency of			
feed utilization			
lbs. TDN/100 lbs. gain	448.2	437.1	472.5
Final weight	724.7	730.0	824.0
Final score			
Conformation	12.1	12.3	12.0

Young Animals on Feed - Purebred

June 1, 1963

	Hereford		Angus		Shorthorn	
	Number individually fed	Number group fed	Number individually fed	Number group fed	Number individually fed	Number group fed
Bulls	12	3	3	2	3	0
Heifers		16		6		10

Additions to

Land, Physical Facilities, and Equipment Used

Item	Number	Actual cash value	Percentage used for breeding project
Corrals	3	\$1,000	60
Feed bunks	3	1,000	60
Stocks	1	200	60
Hay sheds	2	4,000	60
Fencing	1/2 mile	500	60

MONTANA STATE COLLEGE

- I. Station: Montana Agricultural Experiment Station, Bozeman, Montana, and the North Montana Branch Station, Havre, Montana
- II. Project title: Recurrent selection and record of performance selection in open and closed beef cattle herds. W-1 M.S. 873, A.I. 104, North Montana Branch Station 71.
 - A. 1. The establishment of inbred lines of registered Hereford cattle, both horned and polled, that will result in improvement in such characteristics as rate and economy of gain, fertility, nursing ability, longevity, and carcass quality.
 2. Maintain an outbred herd of Herefords with bulls selected and furnished by the purebred breeders. The bulls are to be primarily good, high scoring individuals according to breed association standards.
 - B. Establishment of an improved herd of registered Angus cattle in which the males are selected on a high level of performance as indicated by standard record of performance procedure.
 - C. Investigate feasibility of breeding for specific combining ability through recurrent selection.

III. Personnel:

Montana State College:

Experiment Stations, Bozeman, Montana:

F. S. Willson, leader, Alva E. Flower, leader, J. R. Dynes, R. W. Miller, and N. A. Jacobsen, Ext. Livestock Specialist

North Montana Branch Station, Havre, Montana:

Lanny D. Baumann, leader, Claude Windecker, Superintendent

U. S. Department of Agriculture, Beef Cattle Research Branch, Animal Husbandry Research Division, Agricultural Research Service

U. S. Range Livestock Experiment Station, Miles City, Montana
N. M. Kieffer, Superintendent

Denver, Colorado

R. T. Clark, Coordinator, and J. S. Brinks

IV and V. Nature and extent of work done this year and summary of progress

Bozeman

We indexed 13 Hereford bulls and 15 Angus bulls this year. There were 17 Hereford heifers and 12 Angus heifers fed during the winter. (See tables on Feedlot Performance)

Topcross tests of the progeny of an inbred R.O.P. line and an outbred visually selected herd sires were completed the past year. A four-year study using four sires from each herd were test bred on unrelated stock at the Miles City Station. Production, feedlot, and some carcass comparisons were made and the means presented in the following tables. Due to the fact that there were only visually selected sires available the first year and only R.O.P. sires the second year, the top performing M.C. Line I sire group for each year was included as this line was available all four years.

Table 1.--Steer progeny from ROP vs. visually selected sires 1958-59

Sire	Miles City L I Dom 301	Visual Royal Heir 23	Visual Royal Heir 21
180-day wean.wt. ¹	425.2	389.5	403.7
Weaning score (strs) ³	79	77	76
252-day gain (strs)	621.5	566.8	606.5
Final wt. (strs) ²	1070.5	976.4	1020.4
Slaughter grade ⁴	13.5	10.8	11.5
Carcass grade ⁴	12.5	11.5	10.3

Table 2.--Steer progeny from ROP vs. visually selected sires 1959-60

Sire	Miles City L I Dom 308	ROP MSC Clays Lampl 3	ROP Clays Supreme 2
180-day wean. wt. ¹	416.1	393.5	389.9
Weaning score ³	80	82	83
252-day gain	539.1	580.9	612.5
Final wt. ²	952.3	987.1	1026.1
Slaughter grade ⁴	14.9	11.8	11.8
Carcass grade ⁴	12.9	11.8	10.8

¹ Corrected for age of dam and sex (to heifer equivalent).

² 432-day steer weights.

³ 71-75 low ch; 76-80 Av. ch; 81-85 high ch; 66-70 high good

⁴ 8-12 = Choice; 13-18 = Good

Table 3.--Steer progeny from ROP vs. visually selected sires 1960-61

Sire	Miles City L I Dom 344	ROP Clays Super D	Visual Sir Adv. Dom. Misch. 3
180-day wean.wt. ¹	432.8	413.8	404.5
Weaning score ³	82	83	83
252-day gain	638.4	608.4	601.2
Final wt. ²	1119.4	1054.4	1033.6
Slaughter grade ⁴	12.5	10.8	10.0
Carcass grade ⁴	12.3	11.0	10.8

Table 4.--Steer progeny from ROP vs. visually selected sires 1961-62

Sire	Miles City L I Dom 447	ROP Clays Supreme 12	Visual Sir Royal Heir 2
180-day wean.wt. ¹	410.6	399.3	398.1
Weaning score ³	76	78	75
252-day gain	600.1	647.1	542.8
Final wt. ²	1042.0	1090.2	944.9
Slaughter grade ⁴	12.0	10.8	13.0
Carcass grade ⁴	11.0	11.5	12.3

¹ Corrected for age of dam and sex (to heifer equivalent).

² 432-day steer weights.

³ 71-75 low ch; 76-80 av. ch; 81-85 high ch; 66-70 high good.

⁴ 8-12 = Choice; 13-18 = Good.

In table 1, the visually selected group were somewhat smaller than the Miles City Line I, they made 5.5% less gains, but had superior slaughter and carcass grades. In table 2 where only ROP sires were available to compare with M.C. Line I, they were about the same size, made about 10% greater gains, and were considerably better in slaughter and carcass grades.

The last two years there are within-year comparisons between the visual and ROP sire groups. Table 3 indicates there was very little difference between the visual and ROP groups. These two groups made about 5% less gains than the progeny of the M.C. Line I bull, but the slaughter and carcass grades were superior to M.C. Line I.

Table 4 shows the ROP group were definitely superior in all characteristics to the other two groups. They made 19% greater gains than the visual group and their slaughter and carcass grades were a full grade better.

They made close to 8% greater gains than the M.C.Line I group and had superior slaughter and carcass grades.

The first year the grower committees started selecting the visual sires to use in this test was 1952. The female replacements were selected in the same manner in both the ROP and visual groups. It seems apparent from the limited topcross data presented that the sires which were selected on R.O.P. procedures gave considerably greater weight gains without any sacrifice in slaughter and carcass quality than those sires that were selected according to show standards.

North Montana Branch Station - Havre:

A report of steer progeny is included in table 5. Hay consumption was again limited to 3 pounds after February 1 to increase grain consumption.

Table 5.--Hereford steers feeding trials - North Montana Branch Station
1961-62

	Number tested	Init. wt.	Final wt.	Days on test	Av.Da. gain	Final Cond. score
Rancher III × III	6	397	1016	282	2.20	1 G, 5 Ch.
Rancher III × HL ₂	6	435	1021	266	2.20	3 G, 3 Ch.
Rancher V × V	6	413	971	258	2.16	1 G, 5 Ch.
Rancher V × HL ₂	6	405	1016	250	2.44	6 Ch.
Rancher VII × VII	6	396	968	263	2.17	2 G, 4 Ch.
Rancher VII × HL ₂	6	424	1007	265	2.20	4 G, 2 Ch.
Crossline HL ₁ (813)	6	457	1014	253	2.20	4 G, 1 Ch, 1 St.
Crossline HL ₁ (820)	4	419	982	268	2.10	4 Ch.
Crossline HL ₂ (824)	7	415	996	256	2.27	5 G, 2 Ch.
Crossline HL ₂ (827)	5	375	1014	269	2.38	2 G, 3 Ch.
Crossline HL ₃ (814)	3	387	983	273	2.18	3 Ch.
Crossline HL ₃ (649)	7	410	1035	255	2.45	3 G, 4 Ch.
MC 791 Control	8	456	1050	244	2.43	3 G, 5 Ch.

There was a total of 58 station and 36 rancher steers on feed. Of these 58 station steers, there were 49 crossline steers and 9 purebred steers. The effectiveness of the selection program is being partially tested by loaning ranchers station bulls of known performance and ancestry to use on their commercial cows. Progeny from these matings are being compared to progeny from the ranchers' own bulls to achieve a basis of evaluating the effectiveness of the selection programs insofar as gaining ability, carcass quality, and reproductive performance in commercial calf production are concerned.

Comparison of station line crosses (Havre Lines x MC) with the MC (Miles City Line I) line steers is giving us a check on line performance of bulls for possible future use as herd sires in their own respective line.

The carcass measurements are shown in table 6. Considerable variation in these characteristics was noted.

With respect to percent lean, percent fat, percent bone, and average shear force for the Station steers versus Rancher steers, they rated, respectively, 54.93 and 52.63, 29.60 and 32.30, 15.47 and 15.07, 5.57 and 6.41. Thus, the Havre steers were leaner, slightly greater percent bone, and less shear force required in tenderness evaluation.

Other carcass characteristics are included in table 7.

VI. Application of findings:

It is encouraging to note the increased interest of commercial producers in using indexed sires. This presumably is due to the great demand from feeders for calves sired by indexed sires. The Montana Beef Performance Association has over 200 members with an increase of about 10% of calves that are recorded in their various programs. This association established a Bull Indexing Center at Stanford where over 150 bulls from all parts of the state were fed. Their sale was very successful, averaging \$847.00 for bulls with Individual Performance Registry certificates.

VII. Work planned for the future:

Bozeman Station

The Angus herd program has been using the best indexed bull we could afford no matter where he may be located. We are putting out 3 two-year-old sires with reputation herds in three counties with the option to buy back 8 steer calves from our bulls on rancher cows and 8 steer calves from rancher bulls on his cows. These calves will be put through the feedlot tests and carcasses evaluated. This should give us some idea of how our herd performs in comparison to reputation industry cattle.

Havre

Emphasis will again be upon the same lines as in previous years. One additional rancher cooperator has been secured. This breeder will use the HL₁ line as his topcross matings. It will be 1963-64 before we receive any of the progeny, but we plan to purchase a sample of his present crop to fatten in the lots in the fall of 1963.

Work will continue as usual with the carcass evaluation program. In the future all the work will be done by station personnel with the exception of the shear force tests which will be done at Montana State College in Bozeman.

Table 6.--Carcass measurements - Havre - Rancher Hereford cattle

Mating type	No. tested	Carcass grade	Cold carcass weight	Dressing percent	Length body	Length hind leg	Circum. round	Depth body	Length loin	Width shoulder	Width round	Rib eye area (sq. in.)	Marbling score
Rancher III x III	6	5Ch, 1G	601	61.6	1183	744	896	397	624	434	483	12.37	5.83
Rancher III x HL ₂	6	3Ch, 3G	596	60.6	1188	744	886	386	620	438	489	11.04	5.33
Rancher V x V	6	5Ch, 1G	561	60.1	1181	723	870	380	592	439	481	11.14	5.67
Rancher V x HL ₂	6	6Ch	573	58.7	1181	725	867	381	612	447	483	12.25	5.83
Rancher VII x VII	6	4Ch, 2G	556	59.8	1156	715	869	378	608	432	480	10.94	5.00
Rancher VII x HL ₂	6	2Ch, 4G	572	59.1	1175	740	878	386	611	434	482	11.33	5.00
Crossline HL ₁ (813)	6	1Ch, 4G	581	59.7	1194	734	880	388	613	435	483	12.04	4.83
Crossline HL ₁ (820)	4	4Ch	571	60.6	1163	718	882	380	596	431	488	10.81	5.75
Crossline HL ₂ (824)	7	2Ch, 5G	574	60.0	1176	737	902	381	616	431	485	11.28	5.14
Crossline HL ₂ (827)	5	3Ch, 2G	579	59.4	1177	748	881	387	624	433	489	10.26	5.60
Crossline HL ₃ (814)	3	3Ch	579	61.3	1179	722	880	388	619	448	485	11.92	5.33
Crossline HL ₃ (649)	7	4Ch, 3G	596	60.0	1175	737	904	387	614	443	502	12.08	5.28
MC 791 (Control)	8	5Ch, 3G	605	60.0	1203	742	921	386	616	452	506	11.92	5.25

Table 7.--Summary - Heifer calves - full fed alfalfa hay - 140 days
North Montana Branch Station, Havre
Date: November 29, 1961 to April 18, 1962

Line of Breeding	MC						
	HL ₁	HL ₂	HL ₃	Control	HL ₁	HL ₁	HL ₂
Sire	111	169	739	791	813	820	824
No. of animals	9	15	4	12	4	3	3
Weaning weight	393.0	395.7	450.8	454.8	420.0	424.0	429.7
Weaning age	188.6	175.7	189.0	189.8	175.0	190.0	181.0
180-day correct weight	337.8	409.6	433.3	433.4	429.7	409.7	427.0
Weaning score	73.0	78.7	80.8	80.1	80.0	78.2	81.9
<u>Feedlot Performance</u>							
Initial weight	407.9	408.6	467.8	469.8	428.3	438.0	442.7
Final weight	522.2	531.9	570.8	577.2	547.3	562.7	542.0
Total gain	114.3	123.3	103.0	107.4	119.0	124.7	99.3
Av. daily gain	.82	.88	.74	.77	.85	.89	.71
Average daily gain for all heifers - 0.86 pound per head per day.							

Bull #111 - Disposed of, hump jaw and age.

Bull #169 - Disposed of, age and disability on front quarters.

Bull #820 - Sold, surplus bull.

Bull #827 - Disposed of, line back.

Bull #814 - Disposed of, extremely nervous and very poor conformation.

The past winter, the replacement heifers were fed two pounds of rolled barley in addition to alfalfa hay, ad lib, with the hopes of acquiring more size and scale. We hope this increase in physical development will tend to improve the reproductive performance of yearling heifers being bred for the first time. Conception rates of yearling heifers have been quite low, and additional feed may help to alleviate this problem somewhat.

Previously, using yearling bulls has created some problems insofar as settling cows. Possibly, lack of maturity and size have been some causes of lower conception rates. Beginning with the summer of 1963, there will be a change-over from yearling test bulls to two-year-old bulls in test yards.

Some work along the lines of reproductive physiology is being investigated by station personnel. This work will be done in areas where it will not interfere with the established project. Some things being investigated are: Fertility testing bulls, pelvic measurements, factors pertaining to calving difficulties, and additional work in improving conception rate.

VIII. Publications:

Flower, Alva E. 1962. Crossline breeding within a beef breed for increased production. Mont. State Col. Seventh Beef Prod. Sch. Proc. 7:2-5.

Thompson, LeRoy. 1962. Impact of performance tested cattle on the cattle feeder. Mont. State Col. Seventh Beef Prod. Sch. Proc. 7.

Willson, F. S. 1962. What R.O.P. selected bulls will do for commercial cattle. Mont. State Col. Seventh Beef Prod. Sch. Proc. 7:44-48.

Windecker, Claude. 1962. Comparing ranch and experiment station cattle. Nowest. Livestock Annu. 1962:154-156,164.

Flower, A. E., J. S. Brinks, J. J. Urick, and F. S. Willson. 1963. Selection intensities and time trends for performance traits in range Hereford cattle under mass and recurrent selection. J. Anim. Sci. (In press).

Willson, F. S., A. E. Flower, N. M. Kieffer, and R. W. Miller. 1963. Topcross tests of R.O.P. and visually selected herds of Hereford cattle. Amer. Soc. Anim. Prod. West. Sect. Proc. 14.

PROJECT SUMMARY

Cattle Inventory (Bozeman)
PurebredDate: May 27, 1963
Montana Agricultural Experiment Station

Breed	Hereford	Hereford	Angus	Angus
Line	Visual	ROP	Visual	ROP
Station	Bozeman	Bozeman	Bozeman	Bozeman
Bulls, 12 mos. or over	4	16	8 ³	12
Cows, 2 yrs. or over	17 ²	38 ¹	16	30 ⁴
Heifers, yearlings	3	13	5	7
Bull calves	8	8	8	9
Heifer calves	5	8	10	12
Percentage used for breeding project	60	60	60	60
Estimated cash value	\$9,300	\$27,600	\$12,150	\$19,050

¹One bull at Red Bluff²One bull at Red Bluff³One crossline bull calf⁴One crossline cowCattle Inventory (Havre)
PurebredFiscal Year: 1962-63
North Montana Branch Station

Breed	Hereford	Hereford	Hereford
Line	Line I	Line II	Line III
Station	Havre	Havre	Havre
Bulls, 12 mos. or over	8	13	8
Cows, 2 yrs. or over	29	32	22
Heifers, yearlings	12	9	9
Bull calves	15	13	5
Heifer calves	8	9	10
Percentage used for breeding project	100	100	100
Estimated cash value	\$14,775	\$17,500	\$11,975

Grade

Breed	Hereford	Hereford Crossline Heifers
Line	MC Control	Crossline Heifers
Station	Havre	Havre
Bulls, 12 mos. or over	1	-
Cows, 2 yrs. or over	107	-
Heifers, yearling	13	8
Steer calves	56	-
Heifer calves	33	-
Percentage used for breeding project	100	None
Estimated cash value	\$31,025	\$1,000

Cow Production Data - Bozeman

May 27, 1963

Breed	Hereford		Hereford	
Line	ROP		Visual	
Cows bred to calve as 2-yr.-olds	9		3	
Calves born from 2-yr.-olds				
Alive	5		3	
Dead	0		0	
Cows bred to calve at 3 yrs. and up	28		14	
Calves born from 3-yr.-olds and up				
Alive	25		14	
Dead	1		0	
All calves born				
Alive	30		17	
Dead	1		0	
Total	31		17	
Calves weaned	26		16	
Percent calf crop*				
Birth	81.08		100.00	
Weaning	70.27		94.1	
	Bulls		Heifers	
	No.	Av.	No.	Av.
Average:				
Birth weight	12 ¹	74.4	14 ¹	74.2
Weaning age		196.7		195.2
Weaning weight	12	402.5	14	383.6
Adj. weaning weight				
180 days	12	375.5	13	363.1
Weaning score				
Conformation	12	79.0	14	79.6
			4	77.5
			6	80

*Method used in calculation: Cows bred divided into calves born and calves weaned.

¹Two crossline bulls, one crossline heifer calves not included in averages.

²Two crossline heifers, one crossline bull calves not included in averages.

Cow Production Data - Bozeman (Continued)

May 27, 1963

Breed	Angus		Angus					
Line	ROP		Visual					
Cows bred to calve as 2-yr.-olds	4		0					
Calves born from 2-yr.-olds								
Alive	4		0					
Dead	0		0					
Cows bred to calve at 3 yrs. and up	21		13					
Calves born from 3-yr.-olds and up								
Alive	18		10					
Dead	2		1					
All calves born								
Alive	22		10					
Dead	2		1					
Total	24		11					
Calves weaned	22		10					
Percent calf crop*								
Birth	96.0		84.6					
Weaning	88.0		76.9					
	Bulls		Heifers		Bulls		Heifers	
	No. Av.		No. Av.		No. Av.		No. Av.	
Average:								
Birth weight	15	67.7	7	58.8	5	67.2	5	62.2
Weaning age		202.9		201.7		216.8		194
Weaning weight	15	466.6	7	388	5	489.2	5	356
Adj. weaning weight 180-days	15	419	7	352	5	424	5	332
Weaning score								
Conformation	15	80.7	7	81.3	5	81.5	5	80.2

* Method used in calculation: Cows bred divided into calves born and calves weaned.

Cow Production Data - Havre (Used yearling bulls)

1961-62 calf crop

Breed	Hereford MC		Hereford		Hereford							
Line	Test Herd 791		Test Herd 903		Test Herd 942							
Cows bred to calve as 2-yr.-olds	0		1		1							
Calves born from 2-yr.-olds												
Alive	0		1		1							
Dead	0		0		0							
Cows bred to calve at 3 yrs. and up	29		10		9							
Calves born from 3-yr.-olds and up												
Alive	24		10		8							
Dead	1		0		0							
All calves born												
Alive	24		11		9							
Dead	1		0		0							
Total	25		11		9							
Calves weaned	22		11		9							
Percent calf crop												
Birth	82.8		100		90							
Weaning	75.9		100		90							
	Steers		Heifers		Steers		Heifers					
	No. Av.		No. Av.		No. Av.		No. Av.					
Average:												
Birth weight	14	82	11	83	8	82	3	75	3	88	6	66
Weaning age	12	174	10	165	8	168	3	165	3	179	6	161
Weaning weight	12	431	10	394	8	437	3	380	3	400	6	366
Adj. weaning wt.-180 days	12	442	10	421	8	463	3	403	3	398	6	398
Weaning score:												
cond.												
conf.												

Percent calf crop calculated on basis of: $\frac{\text{calves weaned}}{\text{cows exposed}}$

Percent calf crop (birth): $\frac{\text{live calves born}}{\text{cows exposed}}$

Cow Production Data - Havre

1961-62 calf crop

Breed	Hereford		Hereford		Hereford	
Line	Test Herd HL2 924		Test Herd HL2 930		Test Herd HL3 967	
Cows bred to calve as 2-yr.-olds	1		2		2	
Calves born from 2-yr.-olds						
Alive	0		0		1	
Dead	0		0		0	
Cows bred to calve at 3 yrs. and up	10		8		9	
Calves born from 3-yr.-olds and up						
Alive	6		6		2	
Dead	0		0		0	
All calves born						
Alive	6		6		3	
Dead	0		0		0	
Total	6		6		3	
Calves weaned	6		6		3	
Percent calf crop						
Birth	54.5		60.0		27.2	
Weaning	54.5		60.0		27.2	
	Steers	Heifers	Steers	Heifers	Steers	Heifers
	No. Av.	No. Av.	No. Av.	No. Av.	No. Av.	No. Av.
Average:						
Birth weight	4 83	2 80	2 80	4 75	1 81	2 90
Weaning age	4 460	2 171	2 162	4 164	1 149	2 163
Weaning weight	4 406	2 380	2 343	4 378	1 370	2 404
Adj. weaning wt.- 180 days	4 447	2 394	2 374	4 408	1 430	2 431
Weaning score: conf.						

Percent calf crop calculated on basis of: $\frac{\text{calves weaned}}{\text{cows exposed}}$

Percent calf crop (birth): $\frac{\text{live calves born}}{\text{cows exposed}}$

Cow Production Data - Havre - 1961-62

Breed	Hereford											
Line	Test Herd I 717		Test Herd II		Test Herd III							
Cows bred to calve as 2-yr.-olds	7		9		5							
Calves born from 2-yr.-olds												
Alive	6		6		4							
Dead	-		-		-							
Cows bred to calve at 3 yrs. and up	19		17		14							
Calves born from 3-yr.-olds and up												
Alive	15		14		12							
Dead	1		-		1							
All calves born												
Alive	21		20		16							
Dead	1		-		1							
Total	22		20		17							
Calves weaned	20		20		15							
Percent calf crop												
Birth	80.8		76.9		84.2							
Weaning	76.9		76.9		78.9							
	Bulls		Steers		Heifers							
	No. Av.		No. Av.		No. Av.							
Average:												
Birth weight	9	74	13	71	11	84	9	75	8	73	9	71
Weaning age	8	176	12	184	11	168	9	147	6	176	9	163
Weaning weight	8	377	12	384	11	413	9	310	6	377	9	358
Adj. weaning wt.- 180 days	8	384	12	377	11	436	9	361	6	384	9	385
Weaning score:												
Conf.												

Percent calf crop calculated on basis of: $\frac{\text{calves born alive}}{\text{cows exposed}}$

Percent calf crop (birth): $\frac{\text{live calves born}}{\text{cows exposed}}$

Cow Production Data - Havre - (Used yearling bulls) - 1961-62 calf crop

Breed

Line	Test Herd MSC-005
Cows bred to calve as 2-yr.-olds	2
Calves born from 2-yr.-olds	
Alive	2
Dead	0
Cows bred to calve at 3-yrs. and up	8
Calves born from 3-yr.-olds and up	
Alive	7
Dead	0
All calves born	
Alive	9
Dead	0
Total	9
Calves weaned	9
Percent calf crop	
Birth	90
Weaning	90

	Steers		Heifers	
	No.	Av.	No.	Av.
Average:				
Birth weight	4	84	5	75
Weaning age	4	170	5	178
Weaning weight	4	449	5	408
Adj. weaning wt. 180 days	4	470	5	411
Weaning score:				
Conf.				

Percent calf crop calculated on basis of: $\frac{\text{calves weaned}}{\text{cows exposed}}$

Percent calf crop (birth): $\frac{\text{live calves born}}{\text{cows exposed}}$

Montana Agricultural Experiment Station
Feedlot Performance - Bozeman Date: May 27, 1963

Breed	Here- ford	Here- ford	Here- ford	Here- ford	Angus	Angus	Angus	Angus
Line	Visual	Visual	ROP	ROP	Visual	Visual	ROP	ROP
Sex	Bulls	Heifers	Bulls	Heifers	Bulls	Heifers	Bulls	Heifers
Number on test	2	3	11	14	3	5	12	7
Average:								
Age on test	212	234	214	216	224	212	224	230
Initial wt.	425	471	424	436	512	402	440.7	442
Initial Score								
Conf.	79.5	82	79.6	79.5	81.4	80.2	82.6	81.3
Days on test	140	140	140	140	140	140	140	140
Gain								
Total	264	246	296.4	232	328	187	309	222
Average								
Daily gain	1.88	1.75	2.11	1.65	2.29	1.36	2.26	1.58
Pounds of feed								
/100 lbs.gain	713.75	-	667.4	-	677.45	-	680.9	-
Final wt.	689	716.6	720.5	672.7	824	590	812.4	664.3
Final score								
Conformation	78	83	79.3	79.5	80	80	79.6	78.7

Montana Agricultural Experiment Station
Young Animals on Feed Date: May 27, 1963
Purebred - Bozeman - 1962-63

	Hereford		Angus	
	Number individually fed	Number group fed	Number individually fed	Number group fed
Bulls	13	-	15	-
Heifers	-	17	-	12
Steers	-	6	-	4

North Montana Branch Station
Young Animals on Feed - Havre Date: May 31, 1963

Purebred	Number individually fed	Number group fed	
Bulls	24	-	
Heifers	-	30	
Steers	0		
Grades			Rancher Grades
Bulls	-	None	-
Heifers	-	35	-
Steers	-	35	37

Montana Agricultural Experiment Station
Land, Physical Facilities, and Equipment Used - Bozeman - May 27, 1963

Item	Number	Actual Cash value	Percentage used for breeding project
Beef barn and corrals	1	\$ 18,500	60
Sheds	5	6,300	60
Irrigated land	200 acres	80,000	100
Saddle horses	2	300	60
Misc. equipment		700	60
Total		\$105,000	

North Montana Branch Station
Land, Physical Facilities, and Equipment Used - Havre - 1962-63

Item	Number	Actual cash value	Percentage used for breeding project
Bull barn	1	\$ 15,750	75
Long shed	1	13,750	90
Home pasture	1,780 acres	25,830	90
Home farm land	200 acres	5,400	85
Leased pasture	5,000 acres	49,500	100
A.I. truck	1	1,530	75
Saddle horses	8	720	90
Scale and weigh house (station)	1	1,710	90
Scale and weigh house (lease)	1	630	100
Corrals at home station		2,700	90
Corrals at lease		1,350	100
Cattle squeeze	2	360	100
Cabins at lease	2	1,800	100
Automatic waterers	5	450	90

U. S. RANGE LIVESTOCK EXPERIMENT STATION

I. Station: U. S. Range Livestock Experiment Station, Miles City, Montana

II. Project Titles:

APH dl-1 Rev. The development and testing of methods of measuring performance in beef cattle.

AH dl-1 (Rev. #2). Breed crossing for increased production in beef cattle.

AH dl-2 (Rev. #2). Development of superior lines of beef cattle.

_____ Cooperative study of genetic-environmental interaction at Miles City, Montana, and Brooksville, Florida.

III. Personnel:

U. S. Range Livestock Experiment Station, Miles City, Montana:
Nat M. Kieffer, J. J. Urick, and R. A. Bellows

Montana State College, Bozeman, Montana:
F. S. Willson and A. E. Flower

Office of Coordinator, Denver, Colorado:
R. T. Clark, Coordinator, and J. S. Brinks

IV. and V. Nature and extent of work done this year, and summary of progress and conclusions to date:

Project APH dl-1 Rev. The development and testing of methods of measuring performance in beef cattle.

Five sire groups of Hereford and one sire group of Brown Swiss steers dropped in the spring of 1961 were placed in the feedlot approximately one week after weaning in late October and fed for a 252-day period. At the end of the feeding period all steers were shipped by rail to South Saint Paul, Minnesota, and slaughtered. In addition to collecting carcass data similar to that obtained in previous years (various linear measurements and rib samples for palatability studies), weights of the untrimmed standard primal cuts were obtained. Tables 1 and 2 show weights and gains and selected primal cuts as a percentage of chilled carcass weight, respectively. All steers were stereophotographed 16 days prior to the end of the feeding period. These photographs were used to study the relationships of various length, width, and depth measurements with the wholesale cuts of beef and to develop equations which would be predictive of these wholesale cuts or body proportions.

Table 1.--Average preweaning and postweaning performance of 1961 R.O.P. steers

Trait and No. steers	Breed, sire number, and line of sire					
	Hereford 1061/1	Hereford 1099/10	Hereford 959/1	Hereford 962/MS	Hereford 953/MHA	Brown Swiss 933
No. steers	8	7	7	8	8	8
Birth weight (lb.)	87.4	91.3	86.4	86.5	76.9	102.1
180-day weight (lb.)	427	451	424	429	381	548
Feedlot A.D.G. (252 days)	2.38	2.54	2.38	2.57	2.15	2.69
Final feedlot weight (lb.)	995	1061	1028	1067	918	1230

Table 2.--Selected primal cuts as a percentage of chilled carcass weight of 1961-62 R.O.P. steers

Breed	Sire/ line	No.	Rib	Chuck	Brisket	Round	Loin	Percent carcass in forequarter	Percent carcass in hindquarter	Average chilled carcass weight lb.
			%	%	%	%	%	%	%	
Hereford	1061/1	8	9.51	26.71	4.22	22.54	17.67	52.11	47.60	590
Hereford	1099/10	7	9.28	26.02	4.46	23.28	17.96	51.58	48.27	635
Hereford	959/1	7	9.49	27.18	4.15	22.90	17.68	52.55	47.48	620
Hereford	962/MSC	8	9.33	26.28	4.48	22.19	18.20	51.78	48.04	639
Hereford	953/MHA	8	9.61	26.52	4.33	22.19	18.06	51.80	47.86	542
Brown Swiss	933	8	8.83	26.61	4.16	23.39	17.23	51.49	48.32	718

Project AH dl-1 (Rev. #2). Breed crossing for increased beef production.

The first calves from interbreed crosses involving Hereford, Angus, Charolais, and Brown Swiss cows, and Hereford, Angus, and Charolais bulls were weaned in the fall of 1962. Tables 3 and 4 show birth and weaning weights and scores of the crossbred and contemporary straight-bred steer and heifer calves, respectively.

Table 3.--Birth and weaning weights and scores of straight-bred and crossbred steer calves

Breed cross ¹	Number	Birth weight lb.	180-day weight lb.	Weaning score
H × H	5	79.8	400	77.8
H × C	4	80.8	484	78.0
H × BS	4	87.2	523	77.7
H × A	6	74.0	437	79.3
C × C	6	91.8	462	75.8
C × H	2	99.5	501	82.5
C × BS	5	106.2	518	77.8
C × A	4	98.0	491	81.5
A × A	9	75.7	432	79.4
A × H	5	81.0	436	79.8
A × C	2	76.5	432	80.5
A × BS	7	87.0	495	79.3

¹ H = Hereford; C = Charolais; A = Angus; and BS = Brown Swiss.

Table 4.--Birth and weaning weights and scores of straight-bred and crossbred heifer calves

Breed cross	Number	Birth weight lb.	180-day weight lb.	Weaning score
H × H	8	71.8	399	78.5
H × C	7	77.7	470	81.3
H × BS	4	83.0	494	80.8
H × A	8	68.3	408	79.0
C × C	10	92.5	504	80.3
C × H	7	86.1	447	79.7
C × BS	4	104.3	530	80.8
C × A	9	82.9	442	79.7
A × A	7	72.6	412	80.9
A × H	8	70.1	392	78.4
A × C	9	76.9	446	81.2
A × BS	2	84.0	470	78.0

The Hereford calves were the lightest at weaning, and those calves having Brown Swiss dams, regardless of breed of sire, were the heaviest at weaning time. The largest calves at birth were those out of Brown Swiss cows and sired by Charolais bulls. Calves by Charolais bulls had the heaviest weaning weights when averaged over all breeds of dams.

All steers are being fed on a weight constant basis, and when groups of eight-ten steers reach a weight of between 1000-1050 pounds, they are slaughtered. As of May 19 of this year, 20 steers of the following kinds had reached the desired weight and have been slaughtered. No straight-bred contemporary Angus or Hereford steer had reached 1000 pounds by May 19, 1963.

<u>Breed or breed cross</u>	<u>Number</u>
Angus × Hereford	1
Angus × Brown Swiss	3
Hereford × Angus	2
Hereford × Brown Swiss	2
Hereford × Charolais	2
Charolais × Angus	3
Charolais × Charolais	3
Charolais × Brown Swiss	3
Charolais × Hereford	1

Project AH dl-2 (Rev. #2). Development of superiod lines of beef cattle.

1. Development of inbred lines 11, 12, and 14.

The development of inbred Hereford lines 11, 12, and 14 is being continued. All three of these lines were initiated by crossing two or more inbred lines which were developed at the U. S. Range Livestock Experiment Station. Each of the three lines are two sire lines and each line is composed of 55-60 cows. A flexible system of inbreeding coupled with selection for traits of economic importance is being followed in the development of the lines.

2. Crossing of inbred lines of Hereford cattle.

The first calves from reciprocal crosses among Hereford inbred lines 1, 4, 6, 9, and 10 were weaned in the fall of 1962. Table 5 gives the birth and weaning weights of contemporary straightline and crossline Hereford calves. In addition, average daily gains of the bull calves for the first 168 days of their 196-day postweaning gain tests are shown.

Table 5.--Birth and weaning weights of contemporary straightline and crossline Hereford calves.

Line or line cross	Heifers			Bulls			
	No.	Birth weight	Weaning weight ¹	No.	Birth weight	Weaning weight	168-day ADG on feed
1	2	70	373	3	85	453	3.13
4	2	75	358	2	79	422	2.82(1)
6	1	56	329	3	67	393	2.58
9	1	68	352	4	68	378	2.38
10	2	78	414	3	81	396	2.91
1x4 & 4x1	7	78	444	5	93	468	3.12
1x6 & 6x1	5	69	378	5	79	451	2.87
1x9 & 9x1	4	73	401	5	73	432	2.83
1x10 & 10x1	2	79	386	7	79	413	3.01
4x6 & 6x4	5	71	416	5	73	411	2.81
4x9 & 9x4	3	74	377	7	77	421	2.89
4x10 & 10x4	3	85	409	5	83	408	3.08
6x9 & 9x6	5	65	391	3	71	412	2.69
6x10 & 10x6	5	70	370	5	71	402	2.60
9x10 & 10x9	7	74	396	3	83	437	2.75

¹ Adjusted for age of dam and to 180-days of age.

The crossline bull calves were 19 pounds heavier at weaning than the straightline bulls, whereas the crossline heifers were 29 pounds heavier at weaning than the straightline heifers. This amounts to a 4.7 percent increase in weaning weight for the crossline bulls over the straightline bulls and an increase of 7.8 percent in weaning weight for the crossline heifers over the straightline heifers. The crossline bulls at the end of 168 days on feed had made an average daily gain of 2.88 pounds as compared with 2.73 pounds for the straightline bulls.

3. Selection for carcass traits.

Selection for carcass traits (area of rib eye, decrease fat thickness measured at the 12th rib, tenderness, and cutability) is being practiced in a herd of 60 grade Hereford cows. The herd has been split into two groups of 30 cows each, and the same bull is mated to the same cows two years in succession. The 1963 breeding season constitutes the fourth year in which matings have been made in this herd. All bull calves are left intact until weaning at which time ultrasonics are used as an aid in selecting prospective sires for further use in the herd. All remaining males are castrated and fed out in the feedlot for subsequent slaughter and carcass evaluation.

Project _____ Cooperative study of genetic-environmental interaction at Miles City, Montana, and Brooksville, Florida

Fifteen line 1 heifer calves, one cow, and two yearling bulls were shipped to Brooksville, Florida, in the fall of 1962. This makes a total of 64 line 1 females and four line 1 bulls shipped to Brooksville to date. Approximately 15 line 1 weanling heifers will be shipped this fall to complete the number of line 1 females making up the foundation herd. An equal number of line 1 females and bulls have been retained at this station. Forty-one females and four bulls were shipped from the Brooksville Station to Miles City last fall.

VI. Application of findings:

Breed crossing appears to be an effective breeding program by which production per animal unit can be increased without a substantial increase in land and facilities. Calves by Charolais bulls have had the largest weaning weights when averaged over all breeds of dams used in the crossbreeding study at this station. The use of crossbred females appears to be one of the most important aspects of a comprehensive crossbreeding program when used on a commercial basis. The second phase of the present crossbreeding project will be directed toward investigating the most effective methods of utilizing crossbred females in a continuous breeding program.

The limited amount of data available at the present time from the crossing of inbred lines of Hereford cattle at this station precludes making definite statements as to the future potential of crossing inbred lines on a commercial basis. However, preliminary data of a limited scope would suggest that hybrid vigor in significant amounts for certain traits may be obtained by crossing certain inbred lines within purebreeds of beef cattle.

VII. Work planned for the future:

To continue as outlined with the exception that Phase 2 of the crossbreeding project will be revised to study possible uses of crossbred females in a continuing breeding program.

VIII. Publications:

Kieffer, N. M. 1962. The significance of heritability estimates in animal improvement. Mont. Farmer Stockman. Sept.

Bellows, R. A. 1963. Preliminary results of reproductive physiology and growth studies at the U. S. Range Livestock Experiment Station. U.S.R.L.E.S. Field Day. May. p.7-13.

Brinks, J. S. 1963. Response to selection and inbreeding in a closed line of Hereford cattle. University of Wyoming. Fourth Annu. Beef Cattle Short Course. Feb.

- Brinks, J. S. 1963. Predicting body proportions of beef cattle by photogrammetry. U.S.R.L.E.S. Field Day. May. p.1-5.
- Brinks, J. S., R. T. Clark, and N. M. Kieffer. 1963. Sex differences in response to inbreeding in a line of Hereford cattle. Amer. Soc. Anim. Prod. West. Sect. Proc. 14:V-1-6.
- Clark, R. T., C. C. O'Mary, J. S. Brinks, and N. M. Kieffer. 1963. Sex ratios in Hereford range cattle. Amer. Soc. Anim. Prod. West. Sect. Proc. 14:VII-1-4.
- Kieffer, N. M. 1963. The formation and testing of inbred lines of Hereford cattle. Washington State University Beef Cattle Day. April.
- Kieffer, N. M. 1963. Preliminary results from breed crossing for increased beef production at the U. S. Range Livestock Experiment Station. U.S.R.L.E.S. Field Day. May. p.23-26.
- Shelby, C. E., W. R. Harvey, R. T. Clark, J. R. Quesenberry, and R. R. Woodward. 1963. Estimates of phenotypic and genetic parameters in ten years of Miles City R.O.P. steer data. J. Anim. Sci. 22(2):346-353.
- Urlick, J. J. 1963. Preliminary results from the crossing of Hereford inbred lines at the U. S. Range Livestock Experiment Station. U.S.R.L.E.S. Field Day. May. p.19-22.

PROJECT SUMMARY

Cattle Inventory
Purebred

U. S. Range Livestock Experiment Station

Date: June 1963

Breed	H	H	H	H	H	H	H	H	C	BS	A
Line	1	4	6	9	10	11	12	14			
Station	U. S. Range Livestock Experiment Station										
Bulls, 12 mos. or over	18	6	4	6	5	5	6	7	5	0	2
Cows, 2 yrs. or over	153	37	37	50	45	53	66	56	72	46	64
Heifers, yearlings	28	2	1	1	2	14	17	22	9	0	7
Steer calves											
Bull calves	39	2	5	6	5	18	17	19	13		13
Heifer calves	48	3	0	6	4	17	21	21	13		7
Percentage used for breeding project	100	100	100	100	100	100	100	100	100	100	100
Estimated cash value	\$267,885.00										

Grade							
Breed	H	HXA	HXC	HXBS	CXA	AXBS	CXBS
Line							
Station	U. S. Range Livestock Experiment Station						
Bulls, 12 mos. or over	6	4	4	1	4	1	1
Cows, 2 yrs. or over	213						
Heifers, yearling	40	17	13	4	20	2	3
Steer calves							
Bull calves	60	11	18	9	13	5	3
Heifer calves	55	17	14	5	22	3	5
Percentage used for breeding project	100	100	100	100	100	100	100
Estimated cash value	\$86,190.00						

H = Hereford; C = Charolais; BS = Brown Swiss; and A = Angus

PROJECT SUMMARY

Cattle Inventory (Continued)

Date: June 1963

Purebred

U. S. Range Livestock Experiment Station

Breed	Hereford	Hereford	Hereford	Hereford	Hereford	Hereford
Line	G.E.I. Purchased		4 × 1 ¹ 1 × 4	6 × 1 ¹ 1 × 6	9 × 1 ¹ 1 × 9	10 × 1 ¹ 1 × 10
Station	U. S. Range Livestock Experiment Station					
Bulls, 12 mos. or over	4	2		1		1
Cows, 2 yrs. or over	31					
Heifers, yearlings	9	25	7	5	4	2
Steer calves						
Bull calves	13		3	4	5	7
Heifer calves	10		5	4	6	2
Percentage used for breeding project	100	100	100	100	100	100
Estimated cash value						

Cattle Inventory (Continued)

Date: June 1963

Purebred

U. S. Range Livestock Experiment Station

Breed	Hereford	Hereford	Hereford	Hereford	Hereford	Hereford
Line	6 × 4 ¹ 4 × 6	9 × 4 ¹ 4 × 9	10 × 4 ¹ 4 × 10	9 × 6 ¹ 6 × 9	10 × 6 ¹ 6 × 10	10 × 9 9 × 10
Station	U. S. Range Livestock Experiment Station					
Bulls, 12 mos. or over						
Cows, 2 yrs. or over						
Heifers, yearlings	5	3	3	5	5	7
Steer calves						
Bull calves	4	8	4	5	3	2
Heifer calves	8	3	4	3	6	5
Percentage used for breeding project	100	100	100	100	100	100
Estimated cash value						

¹ Five crossline herds, each herd contained six each of L1, L4, L6, L9, and L10 females.

Xline 1 bred to L1 bull; Xline 2 bred to L4 bull; Xline 3 bred to L6 bull; Xline 4 bred to L9 bull; and Xline 5 bred to L10 bull.

U. S. Range Livestock Experiment Station

Cow Production Data 1962 calf crop

Breed	Hereford			Hereford		
Line	1			9		
Cows bred to calve as 2-yr.-olds						
Calves born from 2-yr.-olds						
Alive						
Dead						
Cows bred to calve at 3 yrs. and up	129 ¹			7 ³		
Calves born from 3-yr.-olds and up						
Alive	89			5		
Dead	7			0		
All calves born						
Alive	89			5		
Dead	7			0		
Total	96			5		
Calves weaned	87 ²			5		
Percent calf crop						
Birth	75.6			83.3		
Weaning	68.5			83.3		
	Bulls		Steers	Heifers		
	No.	Av.	No.	Av.	No.	Av.
Average:						
Birth weight	41	79.1		43	74.5	5 78.2
Weaning age		194.6			194.7	196.2
Weaning weight	41	434.5		43	398.8	5 455.6
Adj. weaning wt.-180 days		408.7			373.6	425.0
Weaning score:						
Condition						
Conformation	29	77.9		36	78.1	5 78.8

- ¹ One cow sold after breeding season and one cow died. Pregnancy status unknown.
- ² Calves by cleanup bulls included in cow production data but not in calf data.
- ³ One cow died after breeding season. Pregnancy status unknown. Percentages computed on 6 remaining cows.

U. S. Range Livestock Experiment Station
Cow Production Data

1962 calf crop

Breed	Hereford			Hereford		
Line	11			12		
Cows bred to calve as 2-yr.-olds						
Calves born						
2-yr.-olds						
Alive						
Dead						
Cows bred to calve at 3 yrs. and up	37			44 ¹		
Calves born from 3-yr.-olds and up						
Alive	30			35		
Dead	2			0		
All calves born						
Alive	30			35		
Dead	2			0		
Total	32			35		
Calves weaned	30			34		
Percent calf crop						
Birth	86.5			81.4		
Weaning	81.1			79.1		
	Bulls		Steers		Heifers	
	No.	Av.	No.	Av.	No.	Av.
Average:						
Birth weight	16	82.3			14 72.5 16 83.4	17 80.7
Weaning age		190.7			191.8 175.4	176.7
Weaning weight	16	431.3			14 403.0 16 398.4	17 369.9
Adj. weaning wt.-180 days		412.4			382.6 406.6	376.2
Weaning score:						
Condition & Conformation	16	77.8			14 80.4 16 75.7	17 78.6

¹One cow died. Pregnancy status unknown. Percentages computed on 43 remaining cows.

U. S. Range Livestock Experiment Station
Cow Production Data

1962 Calf crop

Breed	Hereford			Hereford		
Line	14			Grade		
Cows bred to calve as 2-yr.-olds						
Calves born from 2-yr.-olds						
Alive						
Dead						
Cows bred to calve at 3-yrs. and up	46 ¹			49 ²		
Calves born from 3-yr.-Olds and up						
Alive	43			31		
Dead	0			0		
All calves born						
Alive	43			31		
Dead	0			0		
Total	43			31		
Calves weaned	43			31		
Percent calf crop						
Birth	95.6			64.6		
Weaning	95.6			64.6		
	Bulls		Steers	Heifers		
	No.	Av.	No. Av.	No.	Av.	No. Av.
Average:						
Birth weight	20	80.2		23	72.9	17 81.6 14 72.9
Weaning age		188.2			197.2	185.1 190.0
Weaning weight	20	391.0		23	400.2	17 410.0 14 397.6
Adj. weaning wt.-180 days		376.1			371.7	400.9 379.6
Weaning score:						
Condition & Conformation	20	75.3		23	79.5	17 76.9 14 77.2

¹One cow died. Pregnancy status unknown. Percentages computed on 45 remaining cows.

²One cow died. Pregnancy status unknown. Percentages computed on 48 remaining cows.

1962 Calf crop

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U. S. Range Livestock Experiment Station
Cow Production Data

1962 calf crop

Breed	Hereford			Hereford		
Line	Cross Line 2			Cross Line 3		
Cows bred to calve as 2-yr.-Olds						
Calves born from 2-yr.-olds						
Alive						
Dead						
Cows bred to calve at 3 yrs. and up	30 ¹			30		
Calves born from 3-yr.-olds and up						
Alive	26			25		
Dead	1			0		
All calves born						
Alive	26			25		
Dead	1			0		
Total	27			25		
Calves weaned	26			25		
Percent calf crop						
Birth	93.1			83.3		
Weaning	89.7			83.3		
	Bulls		Steers	Heifers		
	No.	Av.	No. Av.	No.	Av.	No. Av.
Average:						
Birth weight	13	84.9		13	78.5	13 68.8
Weaning age		190.8			187.6	197.8
Weaning weight	13	440.9		13 425.5	12 413.5	13 381.4
Adj. weaning wt.-180 days		421.6		400.2	399.9	353.9
Weaning score:						
Condition & Conformation	13	79.2		13 81.4	12 80.3	13 79.3

¹ One cow died after breeding season. Pregnancy status unknown. Percent computed on 29 remaining cows.

U. S. Range Livestock Experiment Station

Cow Production Data

1962 Calf crop

Breed	Hereford			Hereford		
Line	Cross Line 4			Cross Line 5		
Cows bred to calve as 2-yr.-olds						
Calves born from 2-yr.-olds						
Alive						
Dead						
Cows bred to calve at 3 yrs. and up	30			32		
Calves born from 3-yr.-olds and up						
Alive	27			26		
Dead	0			0		
All calves born						
Alive	27			26		
Dead	0			0		
Total	27			26		
Calves weaned	25			23		
Percent calf crop						
Birth	90.0			81.3		
Weaning	83.3			71.9		
	Bulls	Steers	Heifers	Bulls	Steers	Heifers
	No. Av.	No. Av.	No. Av.	No. Av.	No. Av.	No. Av.
Average:						
Birth weight	13 72.9		12 69.6	14 75.4		9 76.2
Weaning age	190.8		192.3	199.5		193.4
Weaning weight	13 408.2		12 398.2	14 428.1		9 410.0
Adj. weaning wt. 180 days	389.4		377.3	393.7		386.6
Weaning score:						
Condition & Conformation	13 77.1		12 80.0	14 79.4		9 80.8

U. S. Range Livestock Experiment Station

Cow Production Data 1962 calf crop

Breed	Hereford				Hereford							
Line	Carcass #1				Carcass #2							
Cows bred to calve as 2-yr.-olds												
Calves born from 2-yr.-olds												
Alive												
Dead												
Cows bred to calve at 3 yrs. and up	29				29							
Calves born from 3-yr.-olds and up												
Alive	19 ¹				23							
Dead	0				0							
All calves born												
Alive	19				23							
Dead	0				0							
Total	19				23							
Calves weaned	19				22							
Percent calf crop												
Birth	65.5				79.3							
Weaning	65.5				75.9							
	Bulls		Steers		Heifers		Bulls		Steers		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.
Average:												
Birth weight	1	96.0	8	84.3	8	79.1	3	83.0	10	81.8	9	78.9
Weaning age		173.0		180.0		170.9		189.7		186.3		172.2
Weaning weight	1	340.0	8	424.0	8	387.8	3	478.0	10	429.0	9	388.4
Adj. weaning wt. - 180 days		350.0		423.4		403.5		457.3		416.5		402.9
Weaning score:												
Condition & Conformation	1	72.0	8	77.9	8	78.8	3	81.3	10	78.1	9	79.0

¹Two cleanup bulls used--calves included in cow production data but not in calf data.

U. S. Range Livestock Experiment Station

Cow Production Data 1962 calf crop

Breed	H A C BS					
Line	X Bred A ¹			X Bred B ¹		
Cows bred to calve as 2-yr.-olds						
Calves born from 2-yr.-olds						
Alive						
Dead						
Cows bred to calve at 3 yrs. and up	22			22		
Calves born from 3-yr.-olds and up						
Alive	19			17		
Dead	0			1		
All calves born						
Alive	19			17		
Dead	0			1		
Total	19			18		
Calves weaned	19			17		
Percent calf crop						
Birth	86.4			81.8		
Weaning	86.4			77.3		
	Bulls		Steers		Heifers	
	No.	Av.	No.	Av.	No.	Av.
Average:						
Birth weight	1	76.0	7	83.7	11	72.7
Weaning age		188.0		185.9		194.3
Weaning weight	1	440.0	7	481.4	11	473.5
Adj. weaning wt. 180 days		424.0		470.4		443.9
Weaning score:						
Condition & Conformation	1	76.0	7	78.8	11	80.2
	3	79.7	6	78.8	8	80.1

¹Hereford sire bred to Hereford, Angus, Charolais, and Brown Swiss females.

1962 calf crop

Breed	X Bred C ¹						X Bred D ³					
Line												
Cows bred to calve as 2-yr.-olds												
Calves born from 2-yr.-Olds												
Alive												
Dead												
Cows bred to calve at 3 yrs. and up	22 ²						25					
Calves born from 3-yr.-olds and up												
Alive	17						19					
Dead	0						0					
All calves born												
Alive	17						19					
Dead	0						0					
Total	17						19					
Calves weaned	17						19					
Percent calf crop												
Birth	81.0						76.0					
Weaning	81.0						76.0					
	Bulls		Steers		Heifers		Bulls		Steers		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.
Average:												
Birth weight	3	85.0	6	72.3	8	72.5	3	104.7	8	94.8	8	97.
Weaning age		191.3		193.0		181.8		188.7		193.8		194.5
Weaning weight	3	521.3	6	434.0	8	411.3	3	527.3	8	454.0	8	535.
Adj. weaning wt. 180 days		497.0		410.2		406.3		512.3		429.6		502.8
Weaning score:												
Condition & Conformation	3	82.3	6	77.3	8	78.6	3	79.7	8	77.8	8	81.

¹Hereford sire bred to Hereford, Angus, Charolais, and Brown Swiss females.

²One cow sold after breeding season. Pregnancy status unknown, percent computed on 21 remaining cows.

³Charolais sire bred to Hereford, Angus, Charolais, and Brown Swiss females.

U. S. Range Livestock Experiment Station
Cow Production Data

1962 calf crop

Breed						
Line	X Bred E ¹			X Bred F ¹		
Cows bred to calve as 2-yr.-olds						
Calves born from 2-yr.-olds						
Alive						
Dead						
Cows bred to calve at 3-yrs. and up	27			24		
Calves born from 3-yr.-olds and up						
Alive	18			23		
Dead	0			1		
All calves born						
Alive	18			23		
Dead	0			1		
Total	18			24		
Calves weaned	18			23		
Percent calf crop						
Birth	66.7			100.0		
Weaning	66.7			95.8		
	Bulls		Steers		Heifers	
	No.	Av.	No.	Av.	No.	Av.
Average:						
Birth weight	4	90.0	3	96.7	11	85.5
Weaning age		187.8		184.7		195.2
Weaning weight	4	504.0	3	520.7	11	491.3
Adj. weaning wt.-180 days		489.0		510.0		460.1
Weaning score:						
Condition & Conformation	4	78.0	3	79.7	11	78.8

¹Charolais sire bred to Hereford, Angus, Charolais, and Brown Swiss females.

U. S. Range Livestock Experiment Station

Cow Production Data 1962 calf crop

Breed						
Line	X Bred G ¹			X Bred H ¹		
Cows bred to calve as 2-yr.-olds						
Calves born from 2-yr.-olds						
Alive						
Dead						
Cows bred to calve at 3-ysr. and up	24 ²			24		
Calves born from 3-yr.-olds and up						
Alive	21			19		
Dead	0			0		
All calves born						
Alive	21			19		
Dead	0			0		
Total	21			19		
Calves weaned	21			19		
Percent calf crop						
Birth	91.3			79.2		
Weaning	91.3			79.2		
	Bulls		Steers		Heifers	
	No.	Av.	No.	Av.	No.	Av.
Average:						
Birth weight	2	63.5	11	79.5	8	77.8
Weaning age		187.5		185.3		181.3
Weaning weight	2	430.0	11	446.5	8	440.5
Adj. weaning wt.- 180 days		415.5		435.7		438.1
Weaning score:						
Condition & Conformation	2	80.0	11	79.2	8	79.0

¹Angus bull bred to Hereford, Angus, Charolais, and Brown Swiss females.

²One cow sold. Pregnancy status unknown. Percentage computed on 23 remaining cows.

U. S. Range Livestock Experiment Station
Cow Production Data

1962 calf crop

Breed							
Line		X Bred I ¹					
Cows bred to calve as 2-yr.-olds							
Calves born from 2-yr.-olds							
Alive							
Dead							
Cows bred to calve at 3 yrs. and up		24					
Calves born from 3-yr.-olds and up							
Alive		20					
Dead		0					
All calves born							
Alive		20					
Dead		0					
Total		20					
Calves weaned		20					
Percent calf crop							
Birth		83.3					
Weaning		83.3					
		Bulls		Steers		Heifers	
		No.	Av.	No.	Av.	No.	Av.
Average:							
Birth weight		1	75.0	7	82.7	12	74.7
Weaning age		185.0		200.0		203.6	
Weaning weight		1	518.0	7	507.7	12	458.3
Adj. weaning wt. 180 days		506.0		467.1		414.1	
Weaning score:							
Condition & Conformation		1	85.0	7	80.7	12	80.9

¹Angus sire bred to Hereford, Angus, Charolais, and Brown Swiss females.

U. S. Range Livestock Experiment Station
Feedlot Performance

Date: June 1963

Breed	Hereford	Hereford	Hereford	Hereford	Hereford	Charolais
Line	1	9	11	12	14	Charolais
Sex	Bull	Bull	Bull	Bull	Bull	Bull
Number on test	34	4	14	7	5	4
Average:						
Age on test	194.6	194.3	187.9	175.9	197.9	184.8
Initial weight	434.1	450.8	419.4	428.4	447.6	549.0
Weaning score:						
Condition and conformation	79.6	79.3	78.7	78.8	80.0	80.5
Days on test	196	196	196	196	196	196
Gain - Total	528.9	436.0	523.0	535.8	521.7	526.8
Average daily gain	2.70	2.22	2.67	2.74	2.66	2.69
Efficiency of feed utilization lbs.						
TDN/100 lbs. gain	23.04	21.89	23.78	24.55	23.28	23.04
Final weight	963.0	886.8	942.4	964.2	969.3	1075.8
Final score						

Feedlot Performance (Continued)

June 1963

Breed	Hereford	Hereford	Hereford	Hereford	Hereford
Line	X Line 1 ¹	X Line 2 ²	X Line 3 ³	X Line 4 ⁴	X Line 5 ⁵
Sex	Bull	Bull	Bull	Bull	Bull
Number on test	12	11	11	13	14
Average:					
Age on test	194.9	188.5	189.5	190.8	199.5
Initial weight	454.3	436.6	413.8	393.2	418.9
Weaning score:					
Condition and conformation	79.7	79.5	80.4	76.8	79.4
Days on test	196	196	196	196	196
Gain - Total	583.6	607.1	541.5	534.5	569.3
Average daily gain	2.98	3.10	2.76	2.73	2.90
Efficiency of feed utilization lbs.					
TDN/100 lbs. gain	-	-	-	-	-
Final weight	1037.8	1043.7	955.4	927.7	998.2
Final score					

¹ L1 bull bred to L1, L4, L6, L9, L10 cows.

² L4 bull bred to L1, L4, L6, L9, L10 cows.

³ L6 bull bred to L1, L4, L6, L9, L10 cows.

⁴ L9 bull bred to L1, L4, L6, L9, L10 cows.

⁵ L10 bull bred to L1, L4, L6, L9, L10 cows.

U. S. Range Livestock Experiment Station

Young Animals on Feed June 1963

Purebred	Hereford		Charolais	
	Number individually fed	Number group fed	Number individually fed	Number group fed
Bulls	68	61	4	3
Heifers				
Steers				6
Grade				
Bulls	4	21		
Heifers				
Steers		23		

Young Animals on Feed (Continued) June 1963

Purebred	Angus		Crossbreds ¹	
	Number individually fed	Number group fed	Number individually fed	Number group fed
Bulls				
Heifers				
Steers				
Grade				
Bulls		2		14
Heifers				
Steers		9		40

¹ Composed of CXH, HXC, AXH, HXA, CXBS, HXBS, AXBS, CXA, AXC.

Land, Physical Facilities, and Equipment Used June 1963

Item	Number	Actual cash value	Percentage used for breeding project
Land	55,941 acres	\$ 812,500	92
Buildings, corrals, land improvements, fences, residences, etc.		2,500,000	92

UNIVERSITY OF NEVADA

- I. Station: Nevada Agricultural Experiment Station, Reno, Nevada
- II. Project Title: The effect of environment on selection for traits of economic importance, the relative value of several selection criteria, and reproduction studies in range beef cattle. (Project 304 W-1).
- III. Personnel:
- Experiment Station:
C. M. Bailey, C. L. Probert, J. E. Hunter, C. R. Torell, and W. D. Foote.
- U. S. Department of Agriculture, Beef Cattle Research Branch, Animal Husbandry Research Division, Agricultural Research Service, Denver, Colorado:
R. T. Clark, Coordinator, and J. S. Brinks
- IV. and V. Nature and extent of work done this year and summary of progress and conclusions to date:

Correlation Studies

Blood samples obtained from calves started on performance tests at Reno in 1960 and 1961 were analyzed for serum alkaline phosphatase, blood urea, and plasma fat. Data were analyzed within year, line, and sex. There was a significant correlation (0.22)* between plasma fat and age-of-calf. Correlations between blood values and initial weight, test gain, final weight, feed efficiency, and final score were low in magnitude and nonsignificant.

Correlations between performance traits based on the results of tests conducted during the period 1956 to 1962 are given in table 1. Data for calves tested at Reno and Contact were analyzed separately.

Carcass Data

Rib cuts from bulls in Lines 1, 2, and 3 which were slaughtered at the conclusion of tests in 1960 and 1961 were physically separated into fat, lean, and bone. Means for percent fat, lean, and bone were similar for the three lines.

Bulls tested at Reno during 1962-63 which were not retained for breeding were slaughtered. Carcass weights, grades, and loin-eye tracings were obtained.

Bulls tested at Contact (which were not kept for breeding) were shipped to Reno for further feeding. A random half of the bulls in each line (Lines 4 and 5) was implanted with stilbesterol.

Table 1.--Correlations between performance traits according to location and type of analysis

Correlation	Reno ^a		Contact ^b	
	Gross	Within ^c	Gross	Within ^c
Initial weight with test gain	0.20**	-.06	-.08	0.12
Initial weight with gain/cwt.TDN	-.06	-.41**	-.41**	-.38**
Initial weight with final weight	0.79**	0.90**	0.82**	0.93**
Initial weight with final score ^d	0.08	0.32**	0.33**	0.46**
Test gain with gain/cwt.TDN	0.91**	0.81**	0.83**	0.68**
Test gain with gain final weight	0.75**	0.39**	0.48**	0.45**
Test gain with gain final score	0.05	0.11*	0.07	0.24**
Gain/cwt.TDN with final weight	0.52**	-.03	0.10	-.10
Gain/cwt.TDN with final score	-.17**	-.29**	-.09	0.08
Final weight with final score	0.09	0.35**	0.31**	0.51**

^aN=398. Calves on test received ad libitum 2 grass hay: 1 concentrate.

^bN=221. (N=151 for correlations of final score with other traits).
Calves on test received 3 lb. alfalfa pellets plus grass hay ad libitum.

^cWithin year, line, sex.

^dScores from 100 (outstanding) to 67 (cull).

*P < .05.

**P < .01.

Project Revision

A project revision is being prepared. If approved, changes in procedure would be initiated in 1964.

VI. Application of findings:

Information from the correlation study may be of some use in developing selection criteria.

VII. Work planned for the future:

Selection at each of the two locations will be continued according to the revised project outline. Carcass characteristics of the Contact bulls will be studied.

VIII. Publications and manuscripts:

None.

PROJECT SUMMARY

Cattle Inventory

Date: June 1963

Purebred

Nevada Agricultural Experiment Station

Breed	Hereford	Hereford	Hereford	Hereford	Hereford
Line	1	2	3	4	5
Station	Reno	Reno	Reno	Contact	Contact
Bulls,					
12 mos. or over	6	6	5	6	6
Cows,					
2 yrs or over	31	31	29	31	31
Heifers, yearlings	8	8	6	7	4
Bull calves	12	15	13	12	15
Heifer calves	12	12	9	10	9
Percentage used for					
breeding project	100	100	100	100	100
Estimated cash					
value	\$14,750	\$15,050	\$13,150	\$14,350	\$13,950

Nevada Agricultural Experiment Station

Young Animals on Feed

Date: June 1963

Purebred 1962-63

	Hereford	
	Number individually fed	Number group fed
Bulls	61	0
Heifers	64	0
Steers	0	0

Nevada Agricultural Experiment Station
Cow Production Data

Date: June 1963

Breed	Hereford				Hereford				Hereford			
Line	1				2				3			
Cows bred to calve as 2-yr.-olds												
Calves born from 2-yr.-olds												
Alive												
Dead												
Cows bred 1961 to calve 1962 at 3 yrs. and up	31				32				31			
Calves born from 3-yr.-olds and up 1962												
Alive	26				28				28			
Dead	1				3				2			
All calves born 1962												
Alive	26				28				28			
Dead	1				3				2			
Total	27				31				30			
Calves weaned 1962	24 ^d				28 ^d				26			
Percent calf crop 1962												
Birth ^a	84				88				90			
Weaning ^b	77				88				84			
	Bulls		Heifers		Bulls		Heifers		Bulls		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.
Average:												
Weaning age, days	6	193	16	237	12	241	15	223	14	234	12	228
Weaning weight, lb.	6	396	16	441	12	484	15	413	14	458	12	388

$$^a \frac{\text{Calves born alive}}{\text{Cows exposed to bull}} \times 100$$

$$^b \frac{\text{Calves weaned}}{\text{Cows exposed to bull}} \times 100$$

^cCows which died or were removed from the herd after the start of the breeding season for any reason are included in "cows exposed to the bull."

^dThis figure included one calf which was raised on a nurse cow.

Nevada Agricultural Experiment Station
Cow Production Data (Continued)

Date: June 1963

Breed	Hereford				Hereford			
Line	4				5			
Cows bred to calve as 2-yr.-olds								
Calves born from 2-yr.-olds								
Alive								
Dead								
Cows bred to calve at 3-yrs. and up	30				30			
Calves born from 3-yr.-olds and up								
Alive	28				26			
Dead	0				1			
All calves born								
Alive	28				26			
Dead	0				1			
Total	28				27			
Calves weaned	27				23			
Percent calf crop								
Birth	93				87			
Weaning	90				77			
	Bulls		Heifers		Bulls		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.
Average:								
Weaning age, days	14	223	13	235	15	234	8	233
Weaning weight, lb.	14	384	13	369	15	433	8	369

Nevada Agricultural Experiment Station
Feedlot Performance 1962-63

Date: June 1963

Breed	Hereford		Hereford		Hereford	
Line	1		2		3	
Sex	Bulls	Heifers	Bulls	Heifers	Bulls	Heifers
Number on test	6	16	12	15	14	12
Average:						
Age on test, days	205	251	255	236	248	242
Initial weight, lb.	419	403	468	409	436	364
Initial score						
Conformation ^a	83	84	84	84	85	84
Days on test	140	140	140	140	140	140
Gain - Total, lb.	294	234	299	236	312	205
Average daily gain, lb.	2.10	1.67	2.14	1.68	2.23	1.46
Efficiency of feed utilization lb.						
gain/cwt. TDN	24.6	20.2	23.1	20.4	24.8	19.2
Final weight, lb.	713	636	768	645	748	569
Conformation ^a	83	84	83	84	84	83

^aCalifornia Agricultural Extension Circular 451, dated 1956. Scores from 100 (outstanding) to 67 (cull).

Feedlot Performance 1962-63 (Continued)

Date: June 1963

Breed	Hereford		Hereford	
Line	4		5	
Sex	Bulls	Heifers	Bulls	Heifers
Number on test	14	13	15	8
Average:				
Age on test, days	240	252	251	250
Initial weight, lb.	386	357	428	357
Initial score				
Conformation ^a	83	83	84	84
Days on test	140	140	140	140
Gain - Total, lb.	149	132	150	117
Average daily gain, lb.	1.06	0.94	1.07	0.84
Efficiency of feed utilization lb.				
gain/cwt. TDN	16.7	15.8	16.4	14.0
Final weight, lb.	535	489	578	475
Conformation ^a	83	84	83	83

^aCalifornia Agricultural Extension Circular 451, dated 1956. Scores from 100 (outstanding) to 67 (cull).

Nevada Agricultural Experiment Station
Land, Physical Facilities, and Equipment Used

Date: June 1963

Item	Number	Actual cash value	Percentage used for breeding project
Main Station Farm (Reno), land, buildings, etc.	1 only	\$350,000	20
Knoll Creek Substation (Contact)	1 only	100,000	60
Laboratories	1 only	100,000	30

UNIVERSITY OF NEVADA

- I. Station: Nevada Agricultural Experiment Station, Reno, Nevada.
- II. Project Title: The effect of genetic-environmental interactions on selection responses (Project 390 W-1).
- III. Personnel:
- Experiment Station:
C. M. Bailey, C. L. Probert, and H. J. Weeth
- U. S. Department of Agriculture, Beef Cattle Research Branch,
Animal Husbandry Research Division, Agricultural Research
Service, Denver, Colorado:
R. T. Clark, Coordinator, and J. S. Brinks
- IV. and V. Nature and extent of work done this year and summary of progress and conclusions to date:

Summary of the Initial Phase of the Project

Rats were selected for 70-day weight under two sets of conditions. One line was fed a concentrate mixture during the growth period (28 to 70 days of age). Another line received a "roughage" diet during this period consisting of 65% concentrate mixture: 35% ground alfalfa. All rats were maintained on the concentrate mixture except during the growth period. After six generations of selection, random groups of progenies from each line were tested on both diets.

Data were available from 2479 rats. The regression of deviations of unselected progeny of selected parents from controls on generation number was used as an estimate of genetic progress per generation. Least squares procedures were used for analyzing data from the switched-ration trials conducted in generations seven and eight. Estimates of correlated and direct response were obtained from these analyses.

Realized heritabilities for 70-day weight were 0.20 for rats raised on the concentrate diet and 0.16 for the roughage diet. The genetic correlation between growth on roughage (correlated trait) and growth on the concentrate diet was 1.18. The genetic correlation between growth on concentrate and growth on roughage was 0.79.

Poor fertility became a problem in later generations, especially in the line selected for size on the concentrate diet.

Other aspects of the experiment have been reported previously. These include studies on heterosis, sex ratios, and the effect of plane-of-nutrition and selection on litter size, repeatability of litter size, and relative organ size in the rat.

Current Experiment

A new phase of the project designed to test selection responses and fertility levels of rats maintained throughout their lifetime on high and low levels of concentrates has been initiated.

The base population will consist of four-way crosses.

A standard laboratory ration will be fed to the "concentrate" lines. Energy intake of the "low-level" groups will be restricted by incorporating roughage or cellulose into their diets. The results of preliminary trials indicate that rats fed a diet consisting of 15% cellulose: 85% concentrate are comparable in weight at 70 days of age to rats which are maintained on a 100% concentrate diet. Higher levels of cellulose are being tested at the present time.

VI. Application of findings:

There is nothing to add to the statement made last year.

VII. Work planned for the future:

Following a four-way cross, progeny will be assigned to eight sublimes. Selection will be practiced as described in the project outline.

VIII. Publications and Manuscripts:

Kidwell, J. F., H. J. Weeth, L. H. Haverland, C. E. Shelby, and R. T. Clark. 1962. Repeatability of litter size and weight in the laboratory rat. J. Heredity 53:247.

Bailey, C. M., and H. J. Weeth. 1963. Selection for 70-day weight in the rat. Amer. Soc. Anim. Prod. West. Sect. Proc. 14.

NEW MEXICO STATE UNIVERSITY

- I. Station: New Mexico Agricultural Experiment Station, University Park, New Mexico.
- II. Project Title: Breeding beef cattle for Southwestern ranges.
- III. Personnel:
 Experiment Station:
 L. A. Holland, J. H. Knox, and E. E. Ray

 U. S. Department of Agriculture, Beef Cattle Research Branch,
 Animal Husbandry Research Division, Agricultural Research
 Service, Denver, Colorado:
 R. T. Clark, Coordinator, and J. S. Brinks
- IV. and V. Nature and extent of work done this year and summary of progress and conclusion to date:

Live Animal and Carcass Study

Live animal and carcass data were obtained on 18 steers. Some of the live animal and carcass data gathered on 139 steers since 1958 were analyzed and the results presented at the annual Feeder's Day Program. Means of traits are listed in table 1.

Table 1.--Means of live and carcass traits of steers

Trait	Mean
Live traits	
Slaughter age, days	473
Shrunk slaughter weight, lbs.	809
Daily gain in feedlot, lbs.	2.02
Live grade	Av. good
Wither height, inches	42.9
Loin length, inches	8.8
Loin width, inches	12.9
Rump length, inches	18.6
Cannon circumference, inches	7.7
Carcass traits	
Fat thickness 12th rib, inches	.44
Loin eye area, square inches	10.20
Retail high priced cuts from right side of carcass, lbs. ¹	75.0

¹Round + rump + loin + rib, data available on only 78 steers.

Phenotypic correlations computed within rations within years reported in table 2 indicate that the live animal traits studied are not related highly with the carcass traits among animals of the same weight.

Table 2.--Correlations between live and carcass traits¹

Live traits	Carcass traits					
	Fat thickness 12th rib		Loin eye area		Pounds retail high price cuts	
	A	B	A	B	A	B
Shrunk slaughter wt.	0.34**		0.38**		0.75**	
Live grade	.32**	0.12	.24**	-.04	.57**	0.22*
Wither height	.16	-.06	.31**	.11	.59**	.17*
Loin width	.15	.04	.03	-.11	.46**	.28*
Loin length	.05	-.05	.26**	.17*	.39**	.02
Rump length	.04	-.11	.06**	-.11	.20	.01
Cannon circumference	.00	-.27*	.37**	.20*	.47**	.18

¹Correlations listed under Column A are simple correlations.

Correlations listed under Column B are partial correlations with shrunk slaughter weight held constant.

*Significant at 0.05 level.

**Significant at 0.01 level.

An analysis to determine phenotypic, genetic, and environmental correlations between live and carcass traits among animals of the same age was begun.

Birth Weights

A study of birth weights from 1954 through 1961 revealed that "old" line calves were heavier at birth than "outcross" line calves. Surprisingly, the heifer calves in the "old" line were heavier than bull calves in the "outcross" line. Inbreeding coefficients of dams and offspring were slightly higher in the "old" line.

Defective Hearts

Eight animals with defective hearts have been posted by Dr. T. H. Belling since 1958. Six had a ventricular septal defect (See Belling, T. H., Jr. 1962. Veterinary Medicine 57(11):965), one a fenestrated foramen ovale, and one a faulty tricuspid valve. Dr. Belling has tentatively diagnosed five live animals as possessing the ventricular septal defect and one live animal as possessing a foramen ovale leak. These live animals will be used to study the trait.

VI. Application of findings:

Results from the incomplete analysis of the relationship between live and carcass traits indicate that major emphasis cannot be placed on a single live animal trait in selecting for carcass merit.

VII. Work planned for the future:

Complete analysis of live and carcass data. Data will be tabulated and analysis will begin on response to selection in two lines. A project revision will be submitted to the technical committee.

VIII. Publications:

Holland, Lewis A., E. E. Ray, and Carl Sciacca. 1963. Relationship of live and carcass traits of steers. 24th Annu. Feeders Day. New Mexico State University. Mimeog. Rpt.

IX. PROJECT SUMMARY

Cattle Inventory
Purebred

New Mexico Agricultural Experiment Station

Date: June 3, 1963

Breed	Hereford	Hereford
Line	Old	Outcross
Station	Main	Main
Bulls, 12 mos. or over	9	1
Cows, 2 yrs. or over	47	20
Heifers, yearlings	12	4
Bull calves	15	6
Heifer calves	16	4
Percentage used for breeding project	70	70
Estimated cash value	\$42,250	\$10,900

Grade

Breed	Hereford
Line	
Station	Main
Bulls, 12 mos. or over	
Cows, 2 yrs. or over	104
Steer calves	32
Heifer calves	34
Percentage used for breeding project	40
Estimated cash value	\$27,400

New Mexico Agricultural Experiment Station
Cow Production Data Date: Born July 1, 1961-June 30, 1962

Breed	Hereford			Hereford		
Line	Old			Outcross		
Cows bred to calve as 2-yr.-olds	7			3		
Calves born from 2-yr.-olds						
Alive	6			2		
Dead	0			0		
Cows bred to calve at 3 yrs. and up	32			12		
Calves born from 3-yr.-olds and up						
Alive	28			10		
Dead	1			0		
All calves born						
Alive	34			12		
Dead	1			0		
Total	35			12		
Calves weaned	31			12		
Percent calf crop ¹						
Birth	90			80		
Weaning	79			80		

	Bulls		Steers		Heifers		Bulls		Steers		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.
Average:												
Birth weight												
Weaning age	240		240		240		240		240		240	
Weaning weight	14		4		13		3		1		8	
Adj. weaning wt. - 240 days	593		549		470		565		429		468	
Weaning score:												
Condition	14	12.0	4	12.2	13	8.5	3	11.7	1	6.0	8	10.1
Conformation	14	7.2	4	6.5	13	6.3	3	7.0	1	6.0	8	6.5

¹Percent calf crop

$$\text{Birth} = \frac{\text{no. live + dead calves at birth}}{\text{no. cows exposed}} \times 100$$

$$\text{Weaning} = \frac{\text{no. calves weaned}}{\text{no. cows exposed}} \times 100$$

New Mexico Agricultural Experiment Station

Cow Production Data 1962 calf crop

Breed	Hereford			
Line	Grade			
Cows bred to calve as 2-yr.-olds				
Calves born from 2-yr.-olds				
Alive				
Dead				
Cows bred to calve at 3 yrs. and up	87			
Calves born from 3-yr.-olds and up				
Alive	71			
Dead	1			
All calves born				
Alive	71			
Dead	1			
Total	72			
Calves weaned	61			
Percent calf crop				
Birth	83			
Weaning	70			
	Steers		Heifers	
	No.	Av.	No.	Av.
Weaning age	30		31	
Adj. weaning wt. 205-day		423		412
Weaning score; conformation		6.7		6.6

New Mexico Agricultural Experiment Station
Feedlot Performance Completed test in calendar year 1962

Breed	Hereford	
Line	Old	Outcross
Sex	Bull	Bull
Number on test	9	3
Average:		
Age on test	10 months	10 months
Initial weight	694	635
Initial score		
condition		
conformation		
Days on test	140	140
Gain		
Total	290	267
Average daily gain	2.12	1.91
Efficiency of		
feed utilization		
lbs. TDN/100 lbs. gain	482	507
Final weight	984	902
Final score:		
condition		
conformation		

New Mexico Agricultural Experiment Station
Young Animals on Feed Date: June 3, 1963
Purebred

	Hereford	
	Number individually fed	Number group fed
Bulls	4	

Grade

Steers	24
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New Mexico Agricultural Experiment Station
Land, Physical Facilities, and Equipment Used

June 3, 1963

Item	Number	Actual cash value	Percentage used for breeding project
Range land	63,000 acres	\$189,000	33
Farm land	52 acres	52,000	33
Feed lots		30,000	50
Barns	2 only	120,000	70
Meats laboratory	1 only	100,000	10
Pathology laboratory	1 only	40,000	15
Calculators	4 only	2,800	60
Office equipment		600	60

OREGON STATE UNIVERSITY

- I. Station: Oregon Agricultural Experiment Station, Corvallis, Oregon
- II. Project Title: Improvement of beef cattle through breeding methods using basic...physiological differences in rate and efficiency of gains.
- III. Personnel:
 - Oregon State University:
 - Experiment Station:
 - Central Station, Corvallis:
 - Ralph Bogart, leader, Walter Kennick, A. T. Ralston, and D. C. Church
 - Statistics Department:
 - L. D. Calvin
 - Food Science and Technology:
 - Al Anglemier, W. K. Johnston, Franklin Ampy, Frank Hoornbeek, and Ted Willoughby
 - Squaw Butte-Harney Branch Station:
 - W. A. Sawyer and Joe Wallace
 - Eastern Oregon Branch Livestock Station
 - James McArthur
 - Malheur Experimental Area
 - E. N. Hoffman
 - John Jacob Astor Branch Station
 - H. B. Howell
 - U. S. Department of Agriculture, Beef Cattle Research Branch, Animal Husbandry Research Division, Agricultural Research Service, Denver, Colorado:
 - R. T. Clark, Coordinator, and J. S. Brinks

IV. and V. Nature and extent of work done this year and summary of progress and conclusions to date:

Objectives

1. To study the growth pattern of calves differing in rate and efficiency of gains and according to sex, line, and year.
2. Determine the relation of nitrogenous and carbohydrate constituents of the blood and urine to rate and efficiency of gains.
3. Determine the relation of blood enzymes to rate and efficiency of gains.

4. Select for greater rate and efficiency of gains on a ration composed primarily of roughage.
5. To develop and evaluate use of inbred lines.
6. Test bulls of the inbred lines on commercial cows to determine their value as sires of good-doing calves that make desirable carcasses.
7. Study the inheritance of the tendency for chronic bloating.
8. Study the interaction of inheritance and nutrition (or other environmental factors) in causing abnormalities.
9. Determine the use of physiological studies in establishing or assisting in development of reliable indices for beef cattle improvement.
10. Determine the influence of inbreeding on performance traits.
11. Determine relationships between certain physiological factors and carcass value.

Major results of the year:

1. In cooperation with the Squaw Butte Station and U. S. Beef Cattle Breeding Research unit at Denver, data have been analysed from which three manuscripts are being prepared. Heritability was estimated by dam-offspring regression for daily gain on feed, feed efficiency, and daily gain on the range as yearlings where the dams were tested under high versus low levels of feeding. The heritability estimates indicated that feed testing on a low level (primarily roughage) does not permit proper evaluation of an animal's production performance whereas this is accomplished when female animals are fed to gain at approximately two pounds per day. Within subclass correlations of calf performance traits with weight of its dam at 18 or 66 months of age demonstrated that larger and more growthy cows produce calves that gain more rapidly prior to and following weaning.
2. As of December 31, 1962, 58% of the 1962 Hereford and Angus calf crop are on feed test. One Angus bull is off test and several other Angus are nearing the end of the test period (500 to 800 lbs.). Losses have been at a minimum with only two animals lost since birth, one diagnosed as White Muscle Disease and the other as Hydrocephalus. The first diallel mating was made this year among the three Hereford lines as the first step toward 1) testing the genetic values of these lines, 2) determining heterotic effects as a result of line crossing, and 3) developing new lines. Two sires from each Hereford line were used to initiate the diallel cross. The Angus line is being continued as before as a two sire inbred line.
3. The results of the Union study involving the use of sires from the three Hereford lines at the Central Station and from the Union line on

commercial cows accentuated the fact that no one line is superior in all respects as measured by performance and carcass characteristics. Thus, further progress through selection should be accomplished after new lines are established from the diallel mating plan. Scores for conformation and condition at weaning were negatively associated with subsequent performance in the feedlot.

4. A two-year study of Hereford and Angus calves at the Central Station showed that female calves had significantly higher blood urea nitrogen concentrations than male calves and that the concentration increased with increases in age and weight. The rapidly gaining calves had lower blood urea nitrogen concentration than slowly gaining calves. The nitrogenous composition of the blood of rapidly gaining calves was similar to the nitrogenous composition of the blood of younger calves while that of slowly gaining calves resembled the blood composition of older calves. From birth to 800 pounds, serum protein concentration, specific gravity, and serum gamma globulin concentrations increased steadily. Blood components were not consistently correlated with production traits; however, at 500 to 700 pounds body weight periods, urea nitrogen was significantly negatively correlated with rate of gain and positively correlated with feed per unit of gain.

5. A study was conducted to attempt to correlate rate of gain with levels of enzyme activity using Hereford and Angus calves divided according to sex and rapid and slow gainers. Blood samples were taken to determine amylase, alkaline phosphatase, acid phosphatase, cholesterol, serum glutamic-pyruvic transaminase (SGP-T), and serum glutamic-oxalacetic transaminase (SGO-T) content. Early patterns of enzyme activity were found to vary too widely to permit predicting the patterns the animals would develop later, but the study indicated differences in the over-all pattern of the enzymes as related to rate of gain. A possible relationship exists between rate of gain and the ratio of the alkaline-to-acid phosphatase activities. Also, as growth progressed, the progress of enzyme activities seem closely related. The faster gaining animals had smoother plots of activity values as contrasted to irregular patterns of the plots for slow gainers.

6. Electocardiogram recordings, rectal temperatures, and ambient (barn) temperatures were obtained at reference points of 500 to 800 pounds, corresponding to the weights that Hereford and Angus calves were put on and taken off test. The data were collected for a three-year period, with the 500 pound observations being omitted in one year. It was shown that rectal temperatures of smaller calves were more variable than those of larger calves. Rectal temperatures appear to be influenced by ambient temperature because high rectal temperatures tended to be obtained when ambient temperatures were high. There was no correlation found between heart rate and rectal temperatures. Post test diet changes and high ambient temperatures tended to slow heart rate.

VI. Work planned for next year:

1. Continue the diallel mating plan for the three Hereford lines at the Central Station.
2. Gather physiological data on calves produced by the diallel mating.
3. Feed test all bulls and heifers and then carry bulls resulting from the diallel mating to 1000 lb. at which time carcass data will be obtained from all that are not needed for breeding purposes.
4. Continue the Angus line as a two-sire line.
5. Concentrate on preparation of manuscripts for publication from data involving work at the Squaw Butte Station and at the Eastern Oregon Station.
6. Continue to gather data at the Eastern Oregon Station of calf producing ability of cows sired by bulls from the four Hereford lines.

VII. Publications:

- Ampy, Franklin R. 1962. Nitrogenous constituents in the blood of four lines of calves. Ph.D.Thesis. Oregon State University. Corvallis.
- Ampy, Franklin, and Ralph Bogart. 1962. Some physiological studies on growth and feed efficiency in beef cattle (*Bos domesticus*). Amer. Zool. 2(3):170.
- Bogart, Ralph. 1962. Beef cattle breeding research at Oregon State University. Fourth Annual Beef Cattle Day. Oreg. Agr. Expt. Sta. Misc. Paper 132.
- England, Noah C. 1962. Genetic and environmental factors influencing appetite in beef cattle and the relation of appetite to rate and efficiency of gain. Ph.D. Thesis. Oreg. State University. Corvallis.
- Hoornbeek, F. N. 1962. Some genetic and environmental factors associated with performance and carcass traits of beef cattle. M. S. Thesis. Oregon State University. Corvallis.
- Hoornbeek, F. N., J. A. B. McArthur, Ralph Bogart, and W. H. Kennick. 1962. Performance and carcass characteristics in beef cattle. Amer. Soc. Anim. Prod. West. Sect. Proc. 13:XXXII-1-6.
- Johnston, W. K., Jr., A. F. Anglemier, Ralph Bogart, and Marilyn Mack. 1962. Relation of certain blood enzymes to rate of gain in Hereford and Angus cattle. Amer. Soc. Anim. Prod. West. Sect. Proc. 13:III-1-6.

- Krueger, Hugo, and Ralph Bogart. 1962. A frontier of science physiological. Natl. Inst. of Sci. of India Proc. 19.
- Nicholson, H. H., E. N. Hoffman, R. W. Mason, and Ralph Bogart. 1962. Effect of dietary factors upon the hormone content of the anterior pituitary. J. Anim. Sci. 21(3):549-552.
- Van Arsdel, Wm. C., III., and Ralph Bogart. 1962. Ambient temperatures, heart rates, rectal temperatures in beef calves. Amer. Soc. Anim. Prod. West. Sect. Proc. 13:II-1-6.
- Van Arsdel, Wm. C., III., and Ralph Bogart. 1962. The W-P-W syndrome in a Hereford cow. Oreg. Agr. Expt. Sta. Tech. Paper 1603.
- Van Arsdel, W. C., III., Hugo Krueger, and Ralph Bogart. 1962. Vector orientation of P, QRS, and T axes in beef cattle. Oregon Agr. Expt. Sta. Tech. Paper 1637.
- Bogart, Ralph, Joe D. Wallace, R. J. Raleigh, W. A. Sawyer, J. S. Brinks, and R. T. Clark. 1963. Effect of level of concentrate feeding on heritability of performance traits in cattle. Amer. Soc. Anim. Prod. West. Sect. Proc. 14.
- Sawyer, W. A., Ralph Bogart, Joe D. Wallace, R. J. Raleigh, J. S. Brinks, and R. T. Clark. 1963. Relationship among weights of dam and progeny performance. Amer. Soc. Anim. Prod. West. Sect. Proc. 14.
- Wallace, Joe D., R. J. Raleigh, Ralph Bogart, W. A. Sawyer, J. S. Brinks, and R. T. Clark. 1963. Relationship among performance traits in young cattle as influenced by nutritional level. Amer. Soc. Anim. Prod. West. Sect. Prod. 14.

PROJECT SUMMARY

Cattle Inventory

Date: May 6, 1963

Purebred

Oregon Agricultural Experiment Station

Breed	Hereford	Hereford	Hereford	Angus
Line	Lionheart	Prince	David	
Station	Central	Central	Central	Central
Bulls, 12 mos. or over	13	9	11	8
Cows, 2 yrs. or over	22	24	25	24
Heifers, yearlings	6	7	0	8
Bull calves	7	0	1	4
Heifer calves	1	3	4	13
Percentage used for breeding project	100	100	100	100
Estimated cash value	\$14,000	\$12,000	\$11,000	\$14,000

Cattle Inventory (Continued)

Purebred

Breed	Hereford	Hereford	Hereford
Line	Lionheart	Lionheart	Prince
Station	× Prince	× David	× David
Bulls, 12 mos. or over			
Cows, 2 yrs. or over			
Heifers, yearlings			
Bull calves	6	5	6
Heifer calves	4	2	4
Percentage used for breeding project	100	100	100
Estimated cash value	\$1,000	\$700	\$1,000

Oregon Agricultural Experiment Station

Young Animals on Feed

Date: May 6, 1963

Purebred

	Hereford-Lionheart		Hereford-Prince		Hereford-David	
	Number individually fed	Number group fed	Number individually fed	Number group fed	Number individually fed	Number group fed
Bulls	1	-	4	-	4	-
Heifers	5	-	5	-	-	-
Steers	0	-	0	-	0	-

Oregon Agricultural Experiment Station

Cow Production Data

Breed	Hereford				Hereford			
Line	Lionheart				Prince			
Cows bred to calve as 2-yr.-Olds	0				0			
Calves born from 2-yr.-olds								
Alive	0				0			
Dead	0				0			
Cows bred to calve at 3 yrs. and up	17				17			
Calves born from 3-yr.-Olds and up								
Alive	15				13			
Dead	0				0			
All calves born								
Alive	15				13			
Dead	0				0			
Total	15				13			
Calves weaned	15				13			
Percent calf crop ¹								
Birth	88				76			
Weaning	88				76			

	Bulls		Steers		Heifers		Bulls		Steers		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.
Average:												
Birth weight	9	74			6	67	6	78			7	68
Weaning age		180				171		178				191
Weaning weight	9	386			6	319	6	364			7	344
Adj. weaning wt. - 180 days		390				332		372				332
Weaning score:												
Condition	9	10.47			6	10.71	6	10.13			7	10.34
Conformation	9	11.46			6	10.75	6	10.50			7	10.57

¹Birth percent calf crop = $\frac{\text{no. calves born alive}}{\text{total no. cows bred}}$

Weaning percent calf crop = $\frac{\text{no. calves weaned}}{\text{no. cows bred}}$

Oregon Agricultural Experiment Station
Cow Production Data

Breed	Hereford		Angus	
Line	David			
Cows bred to calve as 2-yr.-olds	0		0	
Calves born from 2-yr.-olds				
Alive	0		0	
Dead	0		0	
Cows bred to calve at 3 yrs. and up	14		20	
Calves born from 3-yr.-olds and up				
Alive	7		17	
Dead	0		0	
All calves born				
Alive	7		17	
Dead	0		0	
Total	7		17	
Calves weaned	7		15	
Percent calf crop				
Birth	50		85	
Weaning	50		75	
	Bulls		Heifers	
	No.	Av.	No.	Av.
Average:				
Birth weight	7	71	9	60
Weaning age		182		163
Weaning weight	7	355	7	436
Adj. weaning wt. 180 days		352		478
Weaning scores;				
Condition	7	9.04	7	10.41
Conformation	7	9.32	7	11.61
			8	58
				181
			8	418
				418
			8	10.88
			8	11.53

Oregon Agricultural Experiment Station
Feedlot Performance

Date: May 6, 1963

Breed	Hereford		Hereford		Hereford	Angus	Angus
Line	Lionheart		Prince		David		
Sex	Bull	Heifer	Bull	Heifer	Bull	Bull	Heifer
Number on test	9	6	6	7	7	7	8
Average:							
Age on test	239	281	270	292	277	197	240
Initial weight	500	500	500	500	500	500	500
Initial score:							
Condition	10.47	10.71	10.13	10.34	9.04	10.41	10.88
Conformation	11.46	10.75	10.50	10.57	9.32	11.61	11.53
Days on test*	110	146	118	146	99	119	155
Gain							
Total*	300	300	300	300	300	300	300
Average daily gain*	2.73	2.01	2.62	2.04	3.04	2.57	2.00
Efficiency of feed utilization							
lbs. TDN/100 lbs. gain	530	585	414	521	414	486	621
Final weight*	800	800	800	800	800	800	800
Final score:							
Condition*	11.9	12.7	11.4	11.7	11.7	12.0	12.3
Conformation*	12.4	12.8	11.2	11.7	11.8	12.6	12.7
*Based on number of animals off tests.	8	1	2	2	3	7	4

Oregon Agricultural Experiment Station
Land, Physical Facilities, and Equipment Used

Date: May 6, 1963

Item	Number	Actual cash value	Percentage used for breeding project
Land	240 acres	\$ 24,000	60
Barns	2	\$120,000	40

UTAH STATE UNIVERSITY

I. Station: Utah Agricultural Experiment Station

II. Project Title: The development of breeding techniques and selection criteria for improvement of economically important characteristics in Hereford and Shorthorn cattle.

III. Personnel:

Experiment Station:

J. A. Bennett, D. J. Matthews, Junior Nyman, and Gren Owens

U. S. Department of Agriculture, Beef Cattle Research Branch,
Animal Husbandry Research Division, Agricultural Research Service,
Denver, Colorado:

R. T. Clark, Coordinator, and J. S. Brinks

IV. Nature and extent of work done this year:

The development of two lines of Hereford and one line of Shorthorn cattle was continued. The system in use is that of mild inbreeding accompanied by selection on basis of performance. In addition, a tester herd of known dwarf carrier cows was maintained for testing a young prospective herd bull each year.

Performance in the line appears to be quite satisfactory. The margin in weaning weights in favor of the Shorthorn cattle has narrowed. This year averages show the Shorthorns very near to the line of Herefords maintained at Logan and the Shorthorns being slightly lighter than previous years. Whether this is a result of some increase in inbreeding is not known, or whether it is just a temporary environmental influence, it has not been determined. It appears that the weaning weight of the Hereford is increasing gradually. All the bull calves that were put on performance gain test were self fed this past winter. The gains were exceptionally good with both Herefords and Shorthorns averaging higher than in any previous year. As shown on the accompanying table, the Shorthorns gained an average of 3.64 pounds a day, the line I Herefords 2.83, and the line II Herefords 2.86. These bulls were fed a pellet made similar to that used last year plus about one pound of grass hay fed in the long state.

Adjustment factors were calculated within the Hereford and the Shorthorn breed and within sex within each of these breeds. Early analysis under which adjustment factors were calculated suggested that interaction between age of dam and sex of calf was definitely present and this suggests that adjustment factors within sex basis would be more accurate. The adjustment factors do show a difference within sexes and it is felt more accuracy will be obtained and it is contemplated that adjustment factors will again be calculated after this year's data are collected and this should give more refinement to the adjustments.

The analysis also showed that inbreeding had a significant influence upon weaning weight. Hereford bull calves showed a decrease in weaning weight of 1.86 pounds for each 1 percent increase in inbreeding. In the heifers the decrease was 1.47 pounds per each 1 percent increase in inbreeding. Although the inbreeding levels in the herds are not high they are steadily increasing and the levels are now apparently getting to the point where noticeable effects on weaning weight are present although they are not extremely large.

As a means of attempting to develop a practical and economical test for estimating the amount of fat on the animals, a trial was run in which the fat thickness was actually measured. The technique was patterned after that used for measuring back fat thickness in swine. Reports from other stations that have attempted this have indicated that it has not worked very satisfactorily. It was felt, however, that by applying more care in the technique that it could be made to work. In this test, animals were run into a chute, the skin area was given a local spray-on antiseptic, and a bleeding needle was used for a probe. The skin was first drawn up and the needle inserted through the skin and by a means of a sliding cork on the needle the thickness of the skin was measured. The skin was then released and the needle inserted through the hole in the skin straight down towards the muscle area over the ribs. Measurements were taken over the 9th and 12th rib area. This probe was pushed through the fat until it could be determined that it had come in contact with the covering of the muscle. The cork was then slid down to the surface of the skin and the entire measurement taken on the withdrawn needle and the thickness of the skin deducted giving a net measurement of the back fat thickness. The animals were then slaughtered and the back fat was then measured on the carcass. There was very close agreement between the two measures ($r = .854$). There was also close agreement between the thickness of the back fat as measured on the live animals and the dual grade as put upon the carcass by the Government grader. Only 17 animals were involved in this test but the test does give promise of providing a very economical and a reasonably fast method of estimating back fat thickness in live steers.

V. Summary of progress:

The development of the lines of Hereford and Shorthorn cattle is moving ahead as planned. Production in the lines is very satisfactory and the program at this stage, using a mild inbreeding accompanied by selection, appears to be a promising method. The use of the dwarf tester strain for checking young Hereford bulls before using them in the general herd seems to be very effective in lowering the frequency of dwarf genes in the herd. No dwarf calves have been produced for a number of years and it is doubtful if any of the young sires that have been tested on the 16 carrier cows has been a carrier. Level of inbreeding is still rather low, but it is increasing and it is felt that the lines are approaching a level where preliminary line crosses should be attempted.

Tritium and N-acetyl-4 amino antipyrone have both been shown to be reasonably accurate as a means of estimating body composition in live cattle. Results of the last year's study definitely indicate that a

rather good estimate of the amount of fat covering over the rib area can be obtained by using a probe on live cattle similar to the probing method that has been used successfully on swine. More care is required in making the probe, but if properly done, it does prove to be highly accurate.

Marbling, which has been stressed strongly in the past, and grading of beef were found to have little or no relationship to tenderness in beef carcasses from young steers and heifers of not over 19 months of age. Rate of gain during the immediate preslaughter period was also found to have little or no influence upon tenderness.

VI. Application of findings:

Results of this project would tend to indicate that a system of mild inbreeding accompanied by selection is a safe and a rather effective tool for improving beef cattle for performance characteristics without any loss in carcass value. To date, these results are very encouraging and would give some support of the system as one that could be practiced by purebred breeders. The results also demonstrated to the cattlemen of the state convenient methods of performance testing for gaining ability. Performance testing has been initiated in the state and much of it is being carried on on the farms and ranches. Approximately 1,000 head of animals, mostly purebreds, are now under test each year.

It has been demonstrated that the amount of body fat in live cattle can be estimated with reasonable accuracy by several methods. Most of these, however, are rather complicated and there is still need for a simpler method that can be used under field conditions.

VII. Work planned for the future:

1. Continue to develop lines of Hereford and Shorthorn cattle.
2. Initiate line crossing and test the animals from the cross and compare animals produced from line crossing with those within the line for growth rate and related performance abilities.
3. Continue to study growth in cattle.
4. Continue to investigate methods of estimating body composition and genotype in live cattle.
5. Assist the extension livestock specialist in expanding performance testing activities among the purebred and commercial herds in the state.

VIII. Publications:

Bennett, J. A. 1962. Research in the animal sciences. Farm & Home Sci. 23(3):75, 79.

Matthews, Doyle J., and J. A. Bennett. 1962. Effect of preslaughter rate of gain upon tenderness and other carcass characteristics of beef. J. Anim. Sci. 21(4):738-743.

Matthews, Doyle J., and James A. Bennett. 1963. Does marbling make beef tender? West. Livestock J. 41(9):131-132, 135.

PROJECT SUMMARY

Cattle Inventory
Purebred

Utah Agricultural Experiment Station

Date: June 7, 1963

Breed	Hereford	Hereford	Shorthorn	Grades
Line	I	II	I	Dwarf
Station	Panguitch	Logan	Logan	testers
Bulls, 12 mos. or over	18	4	9	Logan
Cows, 2 yrs. or over	48	13	36	1
Heifers, yearlings	15	3	8	17
Bull calves	23*	4*	16	7
Heifer calves	17*	9	15	10
Percentage used for breeding project	90	90	90	90
Estimated cash value	25,000	8,000	18,000	3,500

*Calving not yet complete.

Utah Agricultural Experiment Station
Cow Production Data

Breed	Hereford		Shorthorn
Line	Panguitch	Logan	Logan
Cows bred to calve as 2-yr.-olds	9	0	8
Calves born from 2-yr.-olds			
Alive	8	0	7
Dead	0	0	0
Cows bred to calve at 3-yr. and up	42	12	29
Calves born from 3-yr.-olds and up			
Alive	39	10	28
Dead	0	1	1
All calves born			
Alive	47	10	35
Dead	0	1	1
Total	47	11	36
Calves weaned	43	11	34
Percent calf crop*			
Birth	92	92	94.6
Weaning	84	92	91.9
	Hereford I	Hereford II	Shorthorn
Average:			
Birth weight	77	73	70
Weaning age - days	208	226	224
Weaning weight	401	442	432
Adj weaning wt. 205 days	395	407	408
Weaning score:			
Condition	3.03	2.21	2.41
Conformation	1.97	1.98	2.02

*Birth = Based on calves born alive to cows bred.

Weaning = Based on calves weaned to cows bred.

Cows culled in fall after breeding are not counted if pregnant. They are counted if open.

Utah Agricultural Experiment Station
Feedlot Performance

June 7, 1963

Breed	Hereford	Hereford	Shorthorn
Line	I	II	I
Sex	Bull	Bull	Bull
Number on test	16	3	7
Initial weight	527	527	626
Initial score condition	2.43	2.5	2.27
Conformation	1.87	1.65	1.95
Average daily gain	2.83	2.86	3.64
Final weight	837	806	938
Final score			
Condition	2.22	1.97	2.0
Conformation	2.12	1.96	2.1

Utah Agricultural Experiment Station
Young Animals on Feed
Purebred

June 7, 1963

	Hereford		Shorthorn	
	Number individually fed	Number group fed	Number individually fed	Number group fed
Bulls		19		7
Heifers		21		8
Steers		14		8

Grade

Bulls			
Heifers	2		
Steers	6		

Utah Agricultural Experiment Station
Land, Physical Facilities, and Equipment Used

Item	Number	cash value	Percentage used for breeding project
Land - Panguitch	155 acres	31,000	90
Land - Logan	330 acres	80,000	80
Shed, yards	5 units	60,000	90
Metabolism Building	1	60,000	5
Laboratory equipment chemical		1,500	100

WASHINGTON STATE UNIVERSITY

- I. Station: Washington Agricultural Experiment Station, Pullman, Washington
- II. Project Title: Comparison of breeding systems for improvement of beef cattle (Project 1692).
- III. Personnel:

Experiment Station:

C. C. O'Mary, M. E. Ensminger,* and W. T. Bennett*

U. S. Department of Agriculture, Beef Cattle Research Branch,
Animal Husbandry Research Division, Agricultural Research
Service, Denver, Colorado:

R. T. Clark, Coordinator, and J. S. Brinks

IV. Nature and extent of work done this year:

The Angus herd was increased to 60 breeding cows and assigned to groups according to the project outline.

V. Summary of progress and conclusions to date:

Very little progress was made because of extremely heavy teaching loads. No conclusions were reached.

VI. Application of findings:

The data are yet to be analyzed.

VII. Work planned for the future:

Plans will be made for next year as soon as the current data are analyzed.

VIII. Publications:

O'Mary, C. C. 1963. A lot depends on management when you substitute rations. Feedlot 5(3):12-13.

O'Mary, C. C. 1963. How size and age affect gains and efficiency. Feedlot. April. p.23.

O'Mary, C. C. 1963. The DNA discovery--may it affect animal breeding? Breeder's Gaz. 128(1):13,24-25.

O'Mary, C. C. 1963. Breeding beef cattle for rate of gain. Breeder's Gaz. 128(3):17-19.

O'Mary, C. C. 1963. You can breed efficient feeders. Breeder's Gaz. April. p.15.

O'Mary, C. C. 1963. Breeding for size in beef cattle. Breeder's Gaz. May. p.12.

PROJECT SUMMARY

Cattle Inventory
Purebred

Date: June 1, 1963
Washington Agricultural Experiment Station

Breed	Angus
Line	Eileenmere
Station	Washington
Bulls, 12 mos. or over	21
Cows, 2 yrs. or over	61
Heifers, yearlings	16
Bull calves	24
Heifer calves	20
Percentage used for breeding project	100
Estimated cash value	\$62,700

Washington Agricultural Experiment Station
Young Animals on Feed
Purebred

	Angus
	Number individually fed
Bulls	14
Heifers	18
Steers	0

Washington Agricultural Experiment Station

Cow Production Data

Date: June 1, 1963

Breed	Angus					
Line	Eileenmere					
Cows bred to calve as						
2-yr.-olds	3					
Calves born from						
2-yr.-olds						
Alive	2					
Dead	1					
Cows bred to calve						
at 3 yrs. and up	37					
Calves born from						
3-yr.-olds and up						
Alive	35					
Dead	1					
All calves born						
Alive	37					
Dead	2					
Total	39					
Calves weaned	37					
Percent calf crop*						
Birth	97.5					
Weaning	92.5					
	Bulls		Steers		Heifers	
	No.	Av.	No.	Av.	No.	Av.
Average:						
Birth weight	21	65.1	None		14	58.3
Weaning age	223				223	
Weaning weight	15	497			12	426
Adj. weaning wt.						
180 days	414				351	

* $\frac{\text{Number of calves}}{\text{Number of cows bred}}$

Washington Agricultural Experiment Station

Feedlot Performance Date: June 1, 1963

Breed	Angus	Angus
Line	Eileenmere	Eileenmere
Sex	Female	Male
Number on test	14	18
Average:		
Age on test	264	264
Initial weight	481	578
Initial score		
Condition		
Conformation		
Days on test	150	150
Gain (average)		
Total	245	366
Average daily gain	1.63	2.44
Efficiency of feed utilization		
lbs. TDN/100 lbs. gain		
Final weight (average)	726	944
Final score condition		
(Average)	2+	2+
Conformation		

UNIVERSITY OF WYOMING

- I. Station: Wyoming Agricultural Experiment Station, Laramie, Wyoming, and Gillette Substation, Gillette, Wyoming
- II. Project Title. W. S. 655. Criteria for improving effectiveness of selection in beef cattle
- III. Personnel:

Experiment Station:
G. E. Nelms, R. A. Field, C. O. Schoonover, and P. O. Stratton

Substation:
Leland Landers and Leon Paules

U. S. Department of Agriculture, Beef Cattle Research Branch,
Animal Husbandry Research Division, Agricultural Research
Service, Denver, Colorado:
R. T. Clark, Coordinator, and J. S. Brinks
- IV. and V. Nature and extent of work done this year and summary of progress and conclusions to date:

Data obtained from various sources were analyzed to study the effects of sex, breeds, age, and weight on several carcass measurements. The study involved 512 animals over a period of seven years. The least squares estimates are presented in table 1.

Increases in length of body, depth of fat, and depth of round, and carcass weight increases were linear when breed, sex, and years were held constant. Area of rib eye tended to level off at the higher weights.

Carcass weight was an accurate predictor of length of body and depth of round when breed, sex, and years were held constant. Carcass weight was not as accurate in predicting area of rib eye. Age was of little value in predicting carcass measurements when carcass weight was known.

The growth study involving individual muscle groups is now up to 420 days of age. Although the data have not been analyzed critically, it would appear that the length of some of the muscles began leveling off at about 360 days. However, the weight of these muscles is continuing to increase in a linear fashion with carcass weight. The data are presented in table 2.

Table 1.--Least squares estimates of the influence of breed, sex, years, and carcass weight on various carcass measurements (N=512)

Variable	Length of body cm.	Depth of Round cm.	Area of rib eye sq. in.	Depth of fat in.
Overall mean	111.39	29.37	9.03	0.42
Breed				
Hereford	-.21	0.51	-.03	-.06
Angus	-.37	-.33	0.64	-.05
Shorthorn	0.24	0.08	-.72	-.03
Crossbreds	0.34	-.27	0.10	0.14
Sex				
Bulls	-.40	0.98	0.68	-.14
Heifers	-1.56	-1.67	-.58	0.01
Steers	1.96	0.69	-.09	0.13
Years				
1955	-1.44	-.69	-1.34	0.05
1956	-.64	-.04	-.42	-.01
1957	1.03	0.18	-.31	-.03
1958	0.58	0.13	-.70	-.03
1959	0.71	0.30	0.52	-.04
1960	-.83	0.07	0.38	0.09
1961	0.58	0.05	1.87	-.03
Weight				
200-299	-12.18	-8.06	-2.66	-.20
300-399	-6.63	-4.36	-1.18	-.10
400-499	-.74	-.86	-.02	-.04
500-599	2.72	2.08	1.07	0.03
600-699	6.65	4.35	1.11	0.11
700-799	10.18	6.85	1.68	0.20

Table 2.--The means for the various muscle measurements at 30-day intervals

Item	Age groups												
	90-120	120-150	150-180	180-210	210-240	240-270	270-300	300-330	330-360	360-390	390-420		
Carcass wt.	94	153	190	218	234	234	295	305	374	410	447		
Longissimus dorsi													
Length (cm.)	53.8	60.2	61.6	63.0	67.7	66.6	70.7	71.5	76.3	75.5	74.6		
Weight (lb.)	2.22	3.46	4.61	4.73	5.10	4.99	5.37	6.26	7.27	8.08	8.54		
Area rib eye (in. ²)	5.71	5.57	7.09	7.77	7.28	7.08	7.39	8.17	9.54	11.58	10.96		
Semitendinosus													
Length (cm.)	26.0	28.5	29.5	32.7	32.9	32.2	31.6	34.0	34.0	32.7	33.7		
Weight (lb.)	0.92	1.48	1.96	2.09	2.26	2.22	2.34	2.91	3.37	3.57	3.79		
Supraspinatus wt. (lb.)	0.48	0.62	0.81	0.92	1.02	1.09	1.24	1.41	1.62	1.70	1.89		
Infraspinatus wt. (lb.)	0.59	0.98	1.37	1.30	1.37	1.37	1.67	1.86	2.11	2.46	2.56		
Forearm group wt. (lb.)	1.09	1.42	1.69	1.79	2.04	1.88	2.35	2.50	2.72	2.85	3.09		
Total wt. of muscles	5.31	7.96	10.44	10.84	11.81	11.23	12.98	14.93	17.03	18.66	19.88		

The synchronization of estrus is being continued. Based on calving data, fertility of the cows that have been synchronized is 43% on the first heat, 45% on the second heat, and the remainder on the third and fourth heat periods. In 1963, 6-chloro-17 hydroxy acetoxypregesterone (CAP, Eli Lilly) is being used in addition to Provera. Only the first estrus data are available (table 3).

Table 3.--Synchronization of estrus in beef cows using progestins (1963 data only)

Treatment	Number of cows	Number in estrus during treatment	No. in estrus 3-5 days post treatment	Percent synchronized
CAP, 10 mg/day 15 days	61	1	51	84
Provera, 200 mg/day 15 days	64	1	56	88

VI. Application of findings:

It would appear from our growth studies that selection for growth rate will result in meatier carcasses. Preliminary examination of the data indicate a close relationship between growth rate and muscle size.

The synchronization of estrus has proved a definite aid to artificial insemination. Detection of estrus is facilitated and calving dates are grouped to some extent.

VII. Work planned for the future:

Selection procedures will be continued as in the past. A selection study involving 10 years' data on the Gillette herd is being analyzed and should be completed within the year. In addition, the study involving muscle growth will be analyzed. Otherwise, the project will be continued as outlined.

VIII. Publications:

Nelms, George, T. R. Varnell, and C. J. Kercher. 1962. Beef cattle research at the University of Wyoming. Stockman Mag.29(12):21-23.

Field, R. A., C. O. Schoonover, G. E. Nelms, and C. J. Kercher. 1963. Evaluation of some old and new beef carcass measurements. Amer. Soc. Anim. Prod. West. Sect. Prod. 14.

Nelms, G. E. 1963. Synchronization of estrus. University of Wyoming. Fourth Annu. Beef Cattle Short Course. February.

Nelms, G. E. 1963. Synchronization of estrus and subsequent fertility in beef cattle. West. Vet. 10:12-16.

PROJECT SUMMARY

Cattle Inventory

Date: June 1, 1963

Purebred

Wyoming Agricultural Experiment Station

Breed	Hereford	Angus	Shorthorn	Hereford
Line				
Station	Laramie	Laramie	Laramie	Gillette
Bulls, 12 mos. or over	7	2	2	5
Cows, 2 yrs. or over	30	35	23	31
Heifers, yearlings	11	8	0	8
Bull calves	16	23	13	16
Heifer calves	13	12	10	11
Percentage used for breeding project	100	100	100	100
Estimated cash value	\$11,125	\$12,100	\$6,900	\$10,750

Grade

Breed	Hereford
Line	
Station	Laramie
Bulls, 12 mos. or over	0
Cows, 2 yrs. or over	13
Bull calves	6
Heifer calves	6
Percentage used for breeding project	100
Estimated cash value	\$3,825

Wyoming Agricultural Experiment Station

Cow Production Data

1962 Calf Crop

Date: June 1, 1963

Breed	Hereford	Angus
Line	Laramie	Laramie
Cows bred to calve as 2-yr.-olds	6	5
Calves born from 2-yr.-olds		
Alive	1	4
Dead	0	0
Cows bred to calve at 3 yrs. and up	38	33
Calves born from 3-yr.-olds and up		
Alive	31	29
Dead	1	0
All calves born		
Alive	32	33
Dead	1	0
Total	33	33
Calves weaned	31	32
Percent calf crop*		
Birth**	87	90
Weaning***	82	87

	Bulls		Heifers		Bulls		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.
Average:								
Birth weight	16	77	15	74	25	55	8	53
Weaning age		189		188		189		194
Weaning weight	16	371	15	343	23	384	8	346
Adj. weaning wt. 180 days		357		332		370		325
Weaning score not taken								

* Some pregnant cows were sold.

** Percent based on pregnancy test in fall

*** Calves weaned/cows exposed

Wyoming Agricultural Experiment Station
Cow Production Data

Date: June 1, 1963

Breed	Hereford		Shorthorn	
Line	Gillette		Laramie	
Cows bred to calve as 2-yr.-olds	7		7	
Calves born from 2-yr.-olds				
Alive	8***		1	
Dead	0		0	
Cows bred to calve at 3 yrs. and up	29		29	
Calves born from 3-yr.-olds and up				
Alive	23		19	
Dead	1		0	
All calves born				
Alive	31		20	
Dead	1		0	
Total	32		20	
Calves weaned	31		19	
Percent calf crop*				
Birth**	89		72	
Weaning***	86		69	
	Bulls		Bulls	
	No. Av.		No. Av.	
	Heifers		Heifers	
	No. Av.		No. Av.	
Average:				
Birth weight	16	78	16	79
Weaning age	190	191	174	151
Weaning weight	16	415	15	381
Adj. weaning wt. 180 days	398	344	391	380
Weaning score not taken				

* Some pregnant cows were sold

** Percent based pregnancy test in fall

*** Calves weaned/cows exposed

**** One heifer had twins

Wyoming Agricultural Experiment Station
Feedlot Performance Date: June 1, 1963

Breed	Hereford		Hereford		Angus		Shorthorn	
Line	Gillette		Laramie		Laramie		Laramie	
Sex	♀	♂	♀	♂	♀	♂	♀	♂
Number on test	15	16	14	16	8	21	3	14
Average:								
Age on test	200	199	198	199	204	203	161	184
Initial weight	364	429	376	399	360	414	353	414
Initial score								
condition	-	-	-	-	-	-	-	-
conformation	-	-	-	-	-	-	-	-
Days on test	168	168	168	168	168	168	168	168
Gain								
Total	272	371	274	380	244	All slaughtered before end of test	322	382
Average daily gain	1.62	2.21	1.63	2.26	1.45		1.92	2.27
Efficiency of								
feed utilization								
lbs.TDN/100 lbs.gain	-	-	-	-	-		-	-
Final weight	636	800	650	779	604		675	796
Final score								
condition	-	-	-	-	-		-	-
conformation	-	-	-	-	-		-	-

Wyoming Agricultural Experiment Station

Young Animals on Feed
Purebred

Date: June 1, 1963

	Hereford		Angus		Shorthorn	
	Number individually fed	Number group fed	Number individually fed	Number group fed	Number individually fed	Number group fed
Bulls	-	32	-	21	-	14
Heifers	-	29	-	8	-	3
Steers	-	0	-	0	-	0

Wyoming Agricultural Experiment Station

Land, Physical Facilities, and Equipment Used

Date: June 1, 1963

Item	Number	Actual cash value	Percentage used for breeding project
Land, grazing land @ \$450/acre	16	\$7,200.00	100
Partial payment TD-6 Caterpillar	1	1,000.00	30
Leland meat mixing machine	1	786.00	50
Table cart	1	125.00	40
Ohm-Microamm Meter	1	71.20	20
Electro-Cell Duostat	1	534.50	30
Electro Kooler	1	95.96	20

August 19

Dr. Nelms:

Since Dr. Wheeler must leave this afternoon, we will rearrange our program and hear from him at this time.

Dr. Wheeler:

I am very much impressed with the talks today. After the introduction by Director Thorne this morning in which he outlined some of the changes in procedures which the Western Directors adopted, I wonder just what the function of an Administrative Adviser remains to be. Since the Directors took it upon themselves to make allotments of funds at the regional level, there is no need for the Committee or Administrative Adviser to become involved in making of allotments.

Then what is the major responsibility of the project leader, the Department Head, with respect to keeping his own Director advised? It becomes most important for the Department Head and project leader to keep the Director well advised as to the project itself. This is what the Director is going to be involved in before he makes a recommendation on Regional Research project funds at the regional level. The Director will be working for a project in the regional context as well as local context. It is not going to be easy to make any very well advised decisions without full information. We must look at this over a period of time, asking ourselves what contribution this state project is making toward the regional project, and also what contribution this project is making per se.

As I see the changes in procedures that now have been initiated, this makes it all the more important that the project leader at state level keep the Director very well informed as to the program and the direction in which his particular state project is going. It is quite obvious. It needs no further emphasis.

What are the responsibilities of the Administrative Adviser? It seems to me one is a continuing one of informing the Directors of one's evaluation of the total project, its progress, such changes as may be indicated with respect to revisions, duration, and particularly publications, out-turn of information, etc. I take it upon myself to assume these responsibilities.

I am very much interested in the W-1 publication. The interest on the part of the Directors is really keen. I certainly hope it will be in circulation soon.

Another responsibility of the Administrative Adviser is to keep himself pretty well informed with respect to whatever evaluation he may be able to make on state projects. We have not been so charged by the Directors, but I do think we are going to have to assume this responsibility in a general fashion, for many Directors feel there must be some

evaluation other than as it comes to them through individual states. This is probably one of the most difficult tasks known--how to evaluate anyone else's work.

All of this about summarizes as I see it what appear to be some of the implications of the new procedure. I think it has all the elements of being entirely workable. It has implications of being quite different both in process and impact, and I think we are going to be quick to see them. But I emphasize the importance of keeping your own people well informed on your project. Some Directors have felt a lack of information or knowledge. This is implicit in the new system--it will be very important to keep your Director well informed. W-1 is in good repute. The Directors will be awaiting the publication with real interest. I would like to ask Dr. Bogart at this moment about the demand.

Dr. Bogart:

We have now firm orders for 12,000. Some indicated they will want more if the price is held down, and if it looks like it is readable. It has been cleared from the courtesy standpoint by the Dean's office and the Department Head's office. The editor has it and all the editing has been done. He wanted to cut out some of the photographs because of his cost estimate. It will be in the hands of the typesetters before the end of September. If the printers can get right on it, it will be right out. The price will be between 20 and 35 cents a copy.

Dr. Burris:

Has it been assigned a number in the Western Series?

Dr. Wheeler:

No. I don't know that it will be assigned a number. Within W-1 it will be No. 1.

I appreciate your permitting me to interrupt the program. I am sorry I can not stay with you tomorrow.

August 20 - 8:00 A.M.

Dr. Nelms:

Some may be curious as to how, in making up the program, a decision was reached as to the stations to make reports. The main reason for choosing the ones we did was our feeling that these stations had data that would most nearly approach our theme in the talks yesterday. They had populations where it would be applied. So, feel free to ask questions along these lines when the project leader is on the floor.

We will have station reports this morning, and after the coffee break we will tour the facilities at USU.

We will start with Arizona.

Dr. Pahnish:

At Arizona we are dealing primarily with heritability.

We have made evaluations on the topcrosses that we have now--topcross progeny from Miles City bulls, Line 1, 3 bulls; Line 6, 2 bulls; Line 9, 2 bulls; Line 10, 2 bulls, in comparison with 8 bulls from the original breeding in the Apache herd at the time this project started. This gives us an opportunity for comparison of topcross progeny from Miles City sires and other sires. The data cover a three-year period, although not all sires were represented every year. Some of the results have been summarized in previous reports.

At fall yearling age (following November) of 594 days, there were several differences between sires from the same sire lines and also significant differences in comparing sires across lines and comparing sires with the original San Carlos breeding. Not always were Miles City sires superior to San Carlos sires. But on the average that was perhaps not true (San Carlos sires being superior not true).

In the range of means for San Carlos breeding, Miles City sires fall within the same range with the exception of one Miles City Line 1 sire. His bull calves were above everything else. We don't know why--maybe chance.

If we compare all Miles City sires versus all San Carlos sires for all traits considered (growth traits, grade, and condition), the means were practically identical. But if we compare in terms of line means it does appear that Line 1 and Line 9 contributed something in the way of growth advantage. Means in terms of gains to weaning, weaning weight, and postweaning growth have been rather consistently above San Carlos breeding. Line 6 would be the average of San Carlos breeding. Line 10 is not quite so easy to evaluate. The heifers were quite good in some respects, the bulls quite uniformly poor in most respects. Up to this time I have been unable to find a topcross bull of Line 10 breeding that we could use. So far as Line 10 is concerned, we have pretty much left that to be absorbed. If they come out in the culling, that is all right. We are hanging onto Line 1, Line 6, and Line 9 material because of the mothering ability of Line 6 and growth of Lines 1 and 9. As breeding cows, Line 6 are showing some advantage of weaning weight.

Regarding work done during the year, the breeding program for 1962-63 was designed for continued accumulation of calf records on topcross females tracing to Miles City 1, 6, 9, and 10 and carrying along with that some of the original San Carlos breeding. During the current year we are getting some additional tests from bulls. We have one Line 1 bull used at Miles City and also at Havre with apparently quite good results and we are using him for the second time this year.

Blood studies as described in the project plan for 1959 are being continued--collection of data for genetic evaluation of various blood constituents. I believe this phase will be discontinued in about 1965. We attempted to get a three-year block of data by collecting blood on every individual animal at weaning, 18 months, and 24 months. We will do the statistical analysis and if anything looks promising we will follow through. We are evaluating cholesterol data. Some heritability estimates have been run and genetic correlations. Some of the findings are reported in tables 4 and 5 of the annual report.

There is one thing we had paid some attention to. We got indications for some concern over running into calving trouble by increasing birth weight. I was interested in getting some idea of just what would happen if we selected for birth weight to improve weaning weight. Birth weight increase of one pound increases weaning weight by two pounds. Shelby's data showed essentially the same. Selecting for increased weaning weight, we get a ratio of approximately 6:1 - 7:1.

There seems to be some indication in this block of data that selection for grade or condition would actually result in increased birth weight. We did get pretty high correlations between weaning weight and grade and gain up to weaning on grade so if we are interested in improving both we should be selecting directly for both. There is no particular reason for selecting for both grade and condition because they are highly correlated.

Dr. Bogart:

Our data indicate that selecting for weaning grade or weaning condition would in time reduce weaning weights.

Dr. Rollins:

I would consider good condition at weaning a positive thing, other things being equal.

Dr. Bogart:

But if this is explained on compensatory relationships, weight would be worth just as much as score.

Dr. Rollins:

I feel that even there the animal getting there first is beginning to fatten earlier than the other because he is ahead physically (we wean at eight months).

Dr. Brinks:

Too much depends on the person who is scoring.

You pooled your correlations between weanling traits, etc. They were high in the light of the heritability estimates you got.

Dr. Pahnish:

The reason for doing that was confidence intervals would be so wide. I don't think we could say there were any major discrepancies between the two sexes except those that may have arisen because of sampling errors, etc. We got some rather high correlations in the pooled block of data, but in every case it is where there is a heritability practically that high.

Dr. Nelms:

Dr. Rollins will report on one of the California projects.

Dr. Rollins:

In view that these talks be related to recombination, I will give a little background.

I have a feeling about crossbreeding. The uses livestock men have made of crossbreeding are:

1. To introduce genes for corrective purposes
2. To exploit hybrid vigor

Examples of the first use are use of Brahman blood to give heat tolerance; second, to exploit hybrid vigor resulting from crossing.

Example of the second use--crossing British breeds under temperate conditions. Crossing with Brahman for heat resistance fits into the first, for heat tolerance. My approach to crossbreeding with British breeds under temperate conditions, the mechanics are different from crossing for heat tolerance (nothing to do with heat tolerance).

Design of experiment:

Breeding season	Bulls	Cows		
		A	H	S
1963	2 Angus	AA	AH	AS
1964	2 Herefords	HA	HH	HS
1965	2 Shorthorn	SA	SH	SS

H A Experiment (sires)

$$\frac{HA + AH}{2} \quad \frac{HH + AA}{2}$$

for evidence of hybrid vigor. If the cross is superior to the straight you say you have hybrid vigor. The livestock man in the field is a little disappointed and says, "Is either one better than the other?" In the first experiment we will not be able to control more than the simple fact.

Going on. I have used a minimum of bulls (not enough cows to use an actual random sample of bulls). Let the random sampling be a regional and interregional affair. Tests are being done all over the country. Why not sample the breed experimentally. All rather follow a model Wright has. Each has set up his own experiment, but when results are available we can compare and when we collate these experiments we are going to have a good sample of bulls and a good sample of cow herds about ten years from now when the results are in we can show some evidence that crossbreeding is good and to what extent.

The two traits we are working with are:

1. Calf crop
2. Shape of the growth curve

In work with inbreeding and in the results from line breeding and line crossing, shape of the growth curve is sensitive to inbreeding and to heterozygotic conditions. In order for this to come out in a clear form, you are dealing with animals that are essentially the same type. But for animals all about the same type, this thing comes out very clearly that the better animals are getting there faster. The effect of inbreeding in the Jersey is most effective at 6 months of age but at 5 years of age it has disappeared.

For the beef producer, we are marketing our animals younger and younger. So this has greater implications because animals are getting there earlier and earlier. In working with the HA experiment the animals are similar enough that this sort of comparison is meaningful. This growth curve fits. The trial showed hybrid vigor, or better stated, hybrid advantage. Hybrid advantage means advantage for the producer. We found for the crossbreds the final weight that year was 52 pounds heavier than the average of straightbreds and they were in higher condition.

We took cutability on them and the straightbreds had significantly higher cutability. This just reflected the fact that the crossbreds were getting there sooner (all were marketed at the same time. If we had marketed the crossbreds a month earlier they would have had the same cutability as the straightbreds). The crossbreds got there about three weeks earlier. Take three weeks on 80 percent concentrate feed and it means about \$12 a head in favor of the crossbreds just because they got there about three to four weeks ahead of the straightbreds.

We are doing complete carcass work on these animals. There are no differences in meat quality between the crossbreds and straightbreds. Organoleptic tests, mechanical tests on tenderness, cutting loss, etc.

The main result was judged in the shape of the growth curve.

Current project 1216. We are here studying crossing of Angus and Shorthorn and will get a measure of calf crop.

There are two phases in this experiment.

Heifers starting from the three breeds. Straightbred and crossbred calves from

1st year	2 Angus bulls
2nd year	2 Hereford bulls
3rd year	2 Shorthorn bulls

Average of all reciprocal crosses.

So far we have bred Angus bulls to Hereford, Angus, and Shorthorn heifers by artificial insemination. We are not too happy with the results. Pregnancy test of August 1 showed (bred January through March so in calf anywhere from 5 to 7 months)

% settled	
Hereford	78.5
Angus	72.4
Shorthorn	66.7

Hereford and Shorthorn, crossbredcalves; Angus straightbred calves. No advantage is shown for the crossbred calves. We are hoping this percentage will come up next year. They will be first-calf cows next year rather than heifers. We also hope our male offspring will be weaned and fed out. We will castrate half and grow half out as steers on stilbestrol and make a very careful test for prejudice against bull meat.

Heifers will be divided (straightbred and crossbred) into two groups. All will be weaned at Davis. At weaning, half will be sent to the ranch, the other half kept at Davis for a year on a rather high plane of nutrition and go to the ranch a year later and bred at the ranch to produce one or more calf crops. We will thus get interaction between breeding and management--comparison of crossbreds and straightbreds under the two different environments.

In the light of the discussion of recombination, I think this has many possibilities and when we finish this experiment we may have some stocks here that we may put into a gene pool.

Dr. Warwick:

I notice in your report you indicate the Hereford-Charbray had no hybrid advantage, but I have not seen the separate figures for the growth of Hereford and Charbray.

Dr. Rollins:

I forgot to mention that. As I recall, there was no difference. However, as you might suspect there were sizable differences between the Charbrays themselves and the Herefords and between the Charbray and the crosses, but in this design the bull effect is not eliminated.

Dr. Warwick:

In other words, there was a considerable advantage of the Charbray.

Dr. Rollins:

Yes, certainly. But no heterosis.

Dr. Burris:

The shape of the growth curve--is that just the same as average daily gain?

Dr. Rollins:

No. In the experiment in the inbreeding studies on the Jerseys we had the mature size, so we had the growth curve. The way I interpret it is you have the better offspring getting to the higher point and beginning to fatten more readily, and this is an aspect of maturing. I am projecting the fact that they will come out to the same size. These are all animals that are marketed at an earlier age than this curve shows.

Dr. Bogart:

How can you describe a growth curve?

Dr. Rollins:

We plotted it and there it was.

Dr. Bogart:

How do you compare one animal with another?

Dr. Rollins:

We are comparing groups of animals.

Dr. Bogart:

Groups? How do you do it?

Dr. Rollins:

We have our various traits. We compare them on that.

Dr. Bogart:

It's just average daily gain.

Dr. Rollins:

I can't give a simple answer because it is not a simple concept. I worked on this with Taylor of Edinburgh--Animal Production.

Dr. Nelms:

Dr. Gregory will report on the other California project.

Dr. Gregory:

Progeny testing for dwarfism, an experiment that started in 1952, has just ended. We have also tested an Oregon bull and a New Mexico bull. We use visual evaluation, then post all of our material.

(Dr. Gregory then showed slides on the results of progeny testing)

Three Hereford bulls were progeny tested for achondroplastic dwarfism under laboratory conditions. Test progeny were systematically weighed and measured; abortions, stillbirths, and calves that died early were autopsied. With the exception of females used for breeding all progeny were autopsied near 16 months of age to obtain 3 metacarpal indices and the time of fusion of the spheno-occipital synchondrosis, (S-O), all diagnostic of achondroplasia. The height at hook bones and weight of all nondwarf test progeny were below standard for registered Herefords. In one bull mated to carriers, the 16 test progeny classified as nondwarf but 6 exhibited lesions of achondroplasia in either the metacarpal indices or the S-O, or both. The second bull had 10 progeny from carriers and all classified as nondwarf but 5 had lesions of achondroplasia in either the metacarpals or S-O, or both. The third sire was tested on carriers, comprest type cows, and dwarfs. The carriers produced 20 progeny, 19 classified as nondwarf, but 2 exhibited early S-O fusion, and one typical dwarf had all the lesions of achondroplasia; the comprest cows produced 17 progeny, 13 nondwarfs, 1 which had intermediate S-O fusion, and 4 dwarfs that had all the lesions of achondroplasia; 21 progeny were produced from dwarfs, 6 were small but nondwarf with no lesions of achondroplasia, 13 were dwarf with all the lesions of achondroplasia; and 2 nondwarfs are yet to be autopsied and classified. Classification of test progeny for achondroplastic dwarfism by visual inspection is ineffective; the accepted hypothesis of inheritance of achondroplasia is untenable.

Dr. Brinks:

When you say three in the dwarf range and one in the normal, what do you decide?

Dr. Gregory:

We decided that he is achondroplastic. We follow these up with progeny testing and things of that sort.

Dr. Holland:

Are you ready to concede that the gene that causes hydrocephalus in the New Mexico herd is not the same gene that causes brachycephalic and achondroplastic calves?

Dr. Gregory:

Why does this bull sire calves with achondroplastic characteristics? We are dealing with the problem of achondroplasia and comprest, compact, Dexter, long-headed, and short-headed dwarfs and all different manifestations of achondroplasia. We cannot fractionate this process of achondroplasia. I think this bull is a potential typical dwarf producer. If you get the right combination of genes you will have dwarfs. Everybody who had started with field data came up with a perfect 3:1 ratio. But we are dealing with a good many characteristics, a good many factors here, so we are trying to disentangle them and see how they all fit together.

Question:

Would you conclude that hydrocephalus is not as simply inherited as has been stated?

Dr. Gregory:

No. We have oversimplified a lot of these points and it is going to take a long time to straighten them out. In the analysis of the New Mexico studies it is segregated out as a simple autosomal recessive, and in some stocks it will segregate as a simple autosomal recessive. But you can take cows of conventional size and bulls of conventional size and mate them together and you don't necessarily have to get a 3:1 ratio. When you use a proband you may get a 3:1 ratio, but you get further complications that will have to be straightened out later.

Dr. Holland:

I maintain you could mate any bull to some of those comprest cows you have and get some comprest calves.

Dr. Gregory:

Everything that has been bred in the past 60 years has been to get something with short legs. With that method of selection they would pick up any gene--concentrate any gene--that would shorten the leg. Just how many we have in here I don't know, and just how complicated it is we don't know, but it is pretty complicated.

Dr. Warwick:

Are we not in danger that we look at this long enough and critically enough until we find something strange about everything?

Dr. Gregory:

We have not had random-bred populations so we are dealing with highly artificial populations to start out with. To get back, you might want to dump all of these cattle together and start another gene pool. It might be something to think about.

Dr. Nelms:

Dr. Stonaker is on sabbatical leave from Colorado State University and Vern Swanson is representing him in this meeting. He will give the Colorado report.

Mr. Swanson:

Dr. Harwin prepared the Colorado report, which has been distributed.

I am going to try to point out some things he thought were rather pertinent.

One study Brad Knapp made was on the mammary system of Hereford cows. This was brought about by the difficulties in the Brae Arden line. He was particularly interested in age, inbreeding, and interaction of age and inbreeding. He found some fairly high heritabilities in the two years' data. The way the heritabilities bounce around, they can serve only as guide lines until there is a chance to study them further.

In the work on synchronizing beef heifers, we have not been too well satisfied with the results from Provera and have dropped the plans for feeding Provera. It was throwing them a little too far behind in the breeding program and messing up the program, so it will not be used this year.

Harwin in his study of the effect of inbreeding cast about for a way to put interactions into a model and determine which were the most representative and include them in a final model. Subclass numbers were erratic.

He came up with four interactions which he thought significant enough to merit further study. His analysis based on his samples followed rather closely the final results on his least squares analysis. He was pleased to find he could sample his data down and have his results come out pretty close with what his least squares analysis had come down to. On his final least squares procedure the interactions to consider were:

- Year $\times$ age of calf
- Year $\times$ age of dam
- Sex $\times$ age of dam
- Sex $\times$ mating system

He was of the opinion that sex $\times$ year interaction also was rather definite and interpreted this to mean that the difference between the heifer and bull calves was wider in favorable years than it was in less favorable years.

Dr. Cobb:

Since we had only routine recombinations occurring in Hawaii, I am not sure why we were asked to report this year. However, we are carrying on the work at the ranch as outlined. We are about to finish the third year of progeny testing at the main station where progeny from this ranch were put to go through the feedlot and slaughtered at 1,000 to 1,050 pounds.

We have been in need of adjustment factors in Hawaii so I was happy to have a graduate student who would accept this assignment. We have had bad years the last three years of this study and there has been a change in the shrinking of cattle before they are weighed and in bringing the cattle in to the corrals they are partially shrunk before they get in. The boy who did this study is the first man with advanced work in Malaya.

We are reporting on the first year's progeny testing on meats data. The animals were on test from 600 to 550 pounds to 1000 to 1050 pounds when slaughtered. So they were not on test the same length of time. There were two different feeding regimes with much different rates of gain. We were trying to determine relationship between yield of trimmed retail cuts and some carcass characteristics. We did not trim these as closely as would be the case in other studies. Also, we have simply the weight of the cut less fat and trim. So there might be a slight difference from other studies. We had only 40 animals. Another difference, we had a narrow range of weights represented here because they were taken off on a weight constant basis. We slaughtered only each two weeks, so there is some difference between treatment groups. The fat cattle would gain faster if they waited two weeks. Those are the two studies that have been completed at Hawaii.

Dr. Nelms:

Professor Willson, will you give the Montana report?

Professor Willson:

The report gives a history of the herds at Bozeman. We had a closed line called the R.O.P. line on Anxiety 4th background closed since 1949. The inbreeding is somewhat too high--probably around 12 percent in some and some are still around 6 percent. Several years ago we divided this group between visually selected and R.O.P. to make some kind of combinations primarily to demonstrate to the local people, the private breeders particularly, who were criticizing the experimental cattle because they were too big, not the right type.

We ran some productivity checks on the cows at the time of the division and found the visually selected group were considerably better in productivity of calf crop, weaning weights, etc., but at the end of the test they checked again and found they moved in opposite directions. The R.O.P. cows kept weaning heavier calves and the visually selected cows weaning lighter calves, same criteria--calf weights, weaning and fall yearling weights, etc.

To check, we produced some outcrosses at Miles City. In this test we used visually selected and R.O.P. bulls on unselected cows. We used Miles City Line 1 all the way through because the first year no R.O.P. sires were available and the second year no visually selected sires. We ran the best performing Miles City Line 1 bull straight through to see how progeny compared with Miles City Line 1. There were some differences. The visually selected group was somewhat smaller than Line 1, 5.5 percent less gain but with superior slaughter and carcass

grade. R.O.P. compared with Miles City Line 1, about the same size, made 10 percent greater gains, and were considerably better in carcass and slaughter data. For the last two years within-year comparisons show very little difference between visually selected and R.O.P. groups. Those years the R.O.P. group failed to excel the Line 1 group. At no time did the visually selected group excel Line 1.

Our breed associations were quite critical, figuring that these cattle would not produce good carcasses. They admitted they were good gaining cattle but did not feel carcasses could be as good. The first two years they visually selected small bulls, but the last two years they selected proven sires just about as big as any in our R.O.P. herd.

Dr. Combs:

Were the cattlemen expecting the conclusions you have drawn?

Mr. Willson:

How do you mean?

Dr. Combs:

Do they say, "It just happened this way."

Mr. Windecker:

There is general acceptance.

Mr. Flower:

There is quite a strong movement in Montana towards R.O.P. work. Most are going into it on the basis of generation after generation production.

Professor Willson:

At Havre, so far as the work is concerned we have three lines bought in 1946, 47, and 48, along in there, closed lines and have been ever since. The procedure is trying to improve the line with R.O.P. procedures. A few years ago outside stock was brought in, steers brought in from six or seven herds and distributed along with our steers from the Havre station. Indications were that our crossline steers were out-performing outside steers by 15 percent on performance and there was a significant difference so far as carcass quality is concerned. The Bozeman steers were intermediate--9 percent better than rancher steers, and about one-third of one percent in carcass quality over rancher steers.

Lanny Bauman will elaborate on what we are doing now.

Lanny Bauman:

The most important thing is the progeny test we are running through on the tester bulls.

We are taking complete carcass measurements. We are going to try to incorporate carcass data in selecting bulls for the herd.

We are switching to two-year-old bulls and a 65-day breeding season. I would like to incorporate some physiology work such as measurements

of pelvis to eliminate calving difficulty, run fertility tests to eliminate nonfertile bulls; also, foot rot has been a problem in young animals although it is negligible in the older animals. We have four rancher cooperators and will send out two bulls to each rancher. We finally have a cooperator on the polled line for the first time.

Professor Willson:

Flower will tell you about the work he and Jim Brinks have been doing.

Professor Flower:

Jim did a nice job getting the material from the cards into an analysis, and a paper will be out in the November Journal of Animal Science, and in the following issue, probably, a follow-up. The first characterizes the lines and the second paper will summarize some of the changes that have occurred. In general the lines have improved if we take into account the environmental trend. There has been a fair amount of selection pressure for weaning weight, daily gain, and final weight on mass selection but a negligible amount so far as the recurrent selection phase is concerned. Now and then a bull would be chosen which was the lesser of a top pair of bulls and therefore there was only a negligible amount of selection pressure.

It was interesting that in the early years for which we had comparisons a pair of bulls within lines on their R.O.P. test if a bull rated 1 and the other rated 2 they would rate this way only about half the time on progeny test. After this time if a bull rated 1 in almost every case his progeny rated 1. So, happenstance or not we lost our opportunity for recurrent selection to be effective. I can not sell this idea to many people, but nevertheless it is in the data. We are interested to see if this continues in the next number of years.

The heritability advantage averaged over the three crosslines

Birth weight	0.1
Weaning weight	4.6
Gain on feed	4.3
Final weight	4.7

Dr. Kieffer: U. S. Range Station Report

In giving the report this year I want to spend most of the time on the crossbreeding and linebreeding projects and will mention only briefly genetic-environmental interactions, carcass work, and the continued development of Lines 10, 11, and 12.

Genetic-environmental interaction work has just been started. We are still transferring cattle to Brooksville. We have transferred 64 Line 1 females, 4 Line 1 bulls, and have received from them about 40 cows and 4 bulls from the Brooksville herd.

Carcass work is continuing as outlined. Sixty grade cows are used in two 30-cow herds, and selection is based only on carcass traits.

Lines 11, 12, and 14 are being developed by crossing lines and we are selecting for traits of economic importance coupled with inbreeding.

In the linecrossing project, five lines are being used. Line 1 is Advance Domino breeding, the line being initiated in 1934. Inbreeding approaches 18 to 20 percent. Line 4 was initiated in 1944, Husker Mischief from Mitchell, New Mexico. Inbreeding is in excess of 15 percent. Line 6, Real Prince Domino from Messersmith in 1947. The inbreeding of the current calves is about 28 percent. Line 9, the polled line, was obtained in 1948 in Montana from Dingwall Hereford Ranch. We do not have the inbreeding. Line 10, Errol Domino--27 daughters of a single sire.

No outside blood has been introduced.

Mating plan.

Line of bull	:	Line of cow				
		1	4	6	9	10
1	:	6	6	6	6	6
4	:	6	6	6	6	6
6	:	6	6	6	6	6
9	:	6	6	6	6	6
10	:	6	6	6	6	6

The cows are reshuffled at the beginning of each breeding season. Each of the five herds contain cows of each line as nearly similar as possible from the standpoint of production, age, and inbreeding.

The first calves were dropped in 1962. They show considerable difference in crossing ability. We don't have a purebred control to compare these with, so since they do carry considerable inbreeding we don't have anything to compare them with.

All crossline bulls were group fed in the feedlot. Average daily gain of the crossline as compared with the straightlines was 2.92 per day for 196 days and 2.77 for the straightline. The crossline bulls weighed 1002 at 196 days and the straight, 943 pounds, but they also went into the feedlot weighing more than the straightline bulls. Line 4x1 cross was particularly striking at weaning and in the feedlot.

Forty-four of the 61 crossline bulls were slaughtered at six months and we obtained various linear carcass measurements and also took the 7th rib cut and sent it to Beltsville for palatability studies, etc. Separation data showed the crossline bulls had 1.5 percent more lean than the straightline bulls. There was considerable range in the rib eye area of these cattle.

We plan on producing one more calf crop and then will have to stop and breed within the line to build up our numbers. Then we will continue the crossing project.

The crossbreeding project involves four breeds of cows and three of bulls, nine herds.

Bulls	C	H	BS	A
C 3	6	6	4	6
H 3	6	6	4	6
A 3	6	6	4	6

We have calves dropped in 1962. We randomly picked 21 bulls and left them intact for puberty study. The remainder went out in the feedlot. Calves from Brown Swiss cows and Charolais bulls had the heaviest calves. Steers were fed to a weight-constant basis of 1000 to 1050 pounds in groups of eight. They were trucked to Billings for slaughter. We just finished slaughtering the last group in mid-July. The cut-off date was July 22. Twelve steers did not make the 1000-pound weight.

<u>Breed cross</u>	<u>No.</u>	<u>ADG</u>	<u>Days on test</u>	<u>Carcass grade</u>	<u>No. not reaching 1000 lb.</u>
A x A	8	2.17	256	10.3	4
A x BS	7	2.26	220	10.3	1
A x C	2	2.17	256	10.0	
A x H	4	2.56	222	10.0	
C x C	6	2.51	213	15.0	
C x A	4	2.61	198	15.5	
C x BS	5	2.45	197	16.0	
C x H	2	2.73	190	13.0	
H x H	5	2.30	257	14.0	3
H x A	6	2.32	230	11.7	2
H x BS	3	2.61	202	12.7	
H x C	4	2.42	218	16.5	

18 - Low Good
 16 - Medium Good
 14 - High Good
 12 - Low Choice
 10 - Medium Choice
 8 - High Choice

We will continue one more year, then start some type of rotational work.

The ranchers are concerned about how to maintain herd replacements if they are going into crossbreeding programs, so this is what we want to work into to see if we can use the crossbred females in a breeding program and have some advantage yet produce an acceptable market animal.

We have had some ideas as to how to make a three-breed cross, back-cross, and straightcross. There is a lot to be considered from the standpoint of measuring producing ability.

Dr. Nelms:

That concludes the station reports which we have asked for, and if there are no questions on the other station reports we will move on into revisions and new projects.

Our thinking is since we have a new policy concerning project revisions we will have Dr. Burris go over this, for it is new to some of us.

Dr. Burris:

I can not add much to what Dr. Thorne said to you the other day. If a project is initiated or a project revised after July 1 of this year, this new project or revision will follow the new procedures, and these in essence include the description of the work in each station contributing in the regional project outline. In other words, supposedly this would give an opportunity to look at all program work in one place in an approved form and perhaps see if we are doing all the things that need to be done and not duplicating the things we are already doing. Perhaps some replication is necessary, but if we have all the work described in one place it will be easier to see if there is some duplication of effort and we can see if the cattle breeding program is moving along without any holes or without any unnecessary duplication. I have supplied Dr. Clark's office with a couple of cases of regional project outlines which have come in and have been approved under this system. I don't know whether it is going to be as effective as they hope it will be or whether it is just another mechanism for getting the job done.

I am not sure on one point, has there been a request for a revision of your project?

Dr. Clark:

No. There was a question on the part of the Directors and the Committee to see if this project was following the objectives as outlined in our project.

Dr. Burris:

I think any time you change the objectives on a project you change the project.

Dr. Bogart:

We did not particularly change the objectives. We just changed the statement of the objectives.

Dr. Burris:

My recollection from last year's meeting was that a revision was desired.

Dr. Bogart:

But we are not going to change the project, only change the sequence of objectives--that is all it amounts to.

Dr. Clark:

We don't feel we should go into a new outline. We have been in a quandary about it and whether your office (CSESS) wants a full-blown project revision, and to that end I asked the states for statements which could be included. I wanted to be sure that anything I wrote with reference to a full-blown project revision would be right. We have not heard from Utah, Idaho, or Washington. We have summaries in a reasonably short form from the other states. We do not consider this an improvement. If an outline is to be drawn up in short form, the shortest we could make it would be about 24 to 26 pages that would tell in adequate fashion what each state is doing. You do at various times mention contributing projects even though you do not use them.

Dr. Burris:

Contributing projects are used but contributing project outlines are not necessary. They may be required by the state Director.

Dr. Clark:

Actually for our purpose in order to be sure that we have a complete history of what a station is doing we would prefer to have a project outline as we have worked with it in the past. I am afraid of this overall outline. We might abbreviate it too much.

Dr. Burris:

I certainly share some of the feelings that are expressed here. However, that does not alter the case. If you send in a 24-page outline you will get it back fast. You can not read that much with all the other things that must be done.

If there is a rewriting of the project, even only a rewriting of the objectives would come under a rewriting of the whole thing--I wonder if there is any necessity for rewriting even the objectives. My recollection was that this committee had decided that a revision of the project was desirable.

Dr. Bogart:

I am sure the feeling of the committee was that a revision of the project was not necessary but only a realignment of the objectives putting them in different sequence and putting them in better English. As I see it now, it would be better just to let it go as they were.

Dr. Burris:

Maybe it would be a good thing to indicate to Dr. Wheeler that while there may be some change in emphasis of objectives none have been eliminated.

Dr. Clark:

It will be all right with you, then, to reword any poorly written ones. Would you say this is a restatement of the objectives?

Dr. Burris:

If you restate the objectives it is going to be considered a revision of the project. So unless you feel these objectives must be restated,

I think you should just let it rest. If in another year you are asked by the Directors you could say you have re-evaluated the objectives and did not feel it was necessary.

I hope this has pretty well cleared the air. Anytime the term revision is used it will require conformation with the new manual.

I think perhaps in response to Dr. Wheeler's request some sort of reply should go back to him following up the action of the Objectives Committee.

Dr. Bogart:

The Objective Committee did make a study and did come up with the idea that the program of work as covered by the objectives was filling the objectives, but that there could be better sequence and there should be better worded statements of objectives. So, in view of this we would be well advised not to try to make a revision now and to advise Dr. Wheeler why we feel this way, and if the Directors still feel that we should revise, Dr. Wheeler will so advise us. This is made as a motion.

Seconded by Dr. O'Mary.

Motion carried.

Dr. Nelms:

We have three projects up for revision--Arizona, Montana, and Nevada.

Dr. Bogart:

From what Dr. Burris said, are we supposed to continue discussion and preparation of these revisions?

Dr. Burris:

So long as you are operating under the old system, and it would be essentially the same under the new system. Now if a new contributing project comes in we follow the same procedure as formerly. The committee accepts it and Dr. Wheeler handles it from there.

Dr. Pahnish:

This is a cooperative project involving the Apache Tribal Council and the University of Arizona, so it does require some type of understanding between the two parties concerned. That has been drawn up recently and has been approved by our own Director and sent back to San Carlos for the required signatures there. So we do have an acceptable agreement outline with the San Carlos people that is in line with what we are hoping to do.

I mentioned briefly this morning that we have some indications that some of the topcrosses show some advantage from the grade standpoint, primarily Line 1 and Line 1 topcrosses and it appears we are getting some advantage from the Line 6 topcross heifer calves at weaning time, indicating advantage in maternal qualities there, so in part this project outline is based on that.

We want to take a further look at these topcrosses, further evaluate their merit, and that is the part we will consider first.

(Dr. Pahnish reviewed the procedures from the project outline).

The second part is a progeny test program. Nine to ten sire complements will be open for a progeny testing program which will permit us to introduce bulls from any likely source whether it be experiment station or private herds which have some records on whatever they might have. That part of the project would be open for further introductions of a superior nature. We may follow through in somewhat the same fashion as with the Miles City breeding. In any case, all bulls are introduced from other experiment stations (I do not make the final decision on that, but the people at San Carlos) wherever it might be possible to introduce good breeding bulls from some of the other experiment stations for testing. It is hoped that the bulls introduced could be bulls that have records so we could continue to gather data. They no doubt would require a plan of some type for release of bulls and gathering of data.

The third part is an investigation of blood constituents. This phase would be a continuation of investigations that started under the present project plan. Blood collection will be completed in 1965 unless there is something we should want to investigate further.

Dr. Bogart:

We will have bulls available from each of our three Hereford lines that will have been used in our own breeding program for a two-year period in Oregon that we could make available at a reasonable rate and we would be interested in seeing them used at another location especially under the extremely variable climatic conditions.

Dr. Pahnish:

I can bring matters of this kind to the attention of the Apache Tribal Council.

Dr. Bogart:

We would have three years that we could supply one bull from each line for each of three years.

Dr. Nelms:

Is there any discussion of the Arizona project.

Dr. Brinks:

On selection criteria in the first phase, you have a lot of genetic correlations on the various traits. Maybe you have used some of that information to set up your selection criteria here. Was any special emphasis placed on any of these?

Dr. Pahnish:

No special emphasis has been assigned yet. I want to get some positive weaning data worked up right away. That will give us some

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Lines 4 and 5 started at 375 pounds, ended at 525 pounds.

These have been one-sire lines, using two-year-old bulls with one exception.

In 1961 in order to get adjustment factors and a general idea of how things were going we analyzed data. For each location environmental effects were about the same in importance but not in magnitude. In the performance tests there were differences between the gain and efficiency lines at Reno. Comparing calves (from lines) between gain and efficiency line and with environment there was very little difference between performance traits. However, we did get a significant line effect on conformation line, about 12 pounds less for 140 days on test. There were no differences in conformation score among lines.

We started with 20 to 25 calves in each line and now have about 30. Inbreeding averages less than 5 percent. For the 1964 calves the inbreeding may average 5% for the five lines.

Starting with 1964 we will make two-sire lines for three years, up to 1967. I hope to analyze all the data and see what has happened in the lines.

In 1965 we would topcross 1964 bulls along with 1961 bulls on cows in as large numbers as possible, and bulls from both environments if possible. We can't guarantee this will be done, but we hope we can. We expect to use a location effect, a selection criteria effect, compare bulls from 1961 and 1964 and get interaction effects.

We will switch a random half of the calves from range environment and pasture environment. (We may not be able to do this because we have anaplasmosis at Knoll Creek.)

As to the conformation line, in 1967 we would want to consider dropping the conformation line. We have had genetic defects in that line. The 1962 bull was a carrier.

In 1967 replacement selection will be for yearling weight. We would like to retain the animals with superior gaining ability.

In 1975 to 1980 we would be switching calves to see how they would do in the other environment.

Routine data would be collected. We would continue progeny testing to 140 days. Weaning weight. Initial weight on test. Final weight. Final score. Slaughter data. We would continue semiannual weights (just as the calves are weaned, and spring). Productivity. Digestion trials. Meats data.

Mr. Swanson:

I move we accept the project with the understanding that it be re-written as presented at this meeting and circulated to the committee.

Dr. Bogart:

Second.

Motion carried.

Mr. Willson distributed "Plans for Bozeman and Havre Montana Agricultural Experiment Station in Line with Revised W-1 Beef Cattle Breeding Project."

Dr. Bogart:

I move that action be taken after the meeting and after the committee members have had an opportunity to study the project. If it is not actually a project revision, then it need not be presented. (Later agreed that it is a revision.)

Dr. Bennett:

Second the motion.

Motion carried.

Mr. Flower:

Carcass data are going to be changed so we can get lean cut yield estimates and tenderness score.

Assessing annual genetic progress at Bozeman has been impossible because of lack of overlapping repeat matings. These will be obtained. At Havre some have been available, but we have spelled it out so none will be missing.

Work on measuring backfat thickness possibly could be brought into our Havre and Bozeman work.

Northern Montana will progeny test three or more sires per year in closed line matings. Topcrossing tests have been entirely too scarce and we hope to push them up considerably with more tests.

Other objectives have been spelled out a bit more fully.

Just a word on what we have been doing at Havre.

The best two bulls each year have been nominated for use--Lines I, II, and III. Line IV is an independent line. The best two bulls have been used on the tester line and the better of the two is used as the herd bull in Line 1, 2, or 3.

We are feeding out all bulls.

Mass selection with a progeny test phase which corrected any error the mass selection had in it.

Dr. Burris:

From our standpoint, I think we would encourage a revision of the project and I think there are several revisions to the objectives.

The pilot work I don't know what the decision might be on that.
But certainly it is up to you folks.

Mr. Flower:

I think Dr. Clark feels the same about this. I would like it to be considered a revision.

Mr. Willson:

We will proceed to prepare a revision.

Dr. Bogart:

It will be put in the minutes as a part of my earlier motion that a revision is to be prepared and circulated by mail to the members of the committee for action.

Dr. Nelms:

We should entertain nominations of a new Chairman. In the past it has been in an alphabetical order by states, but you might want to make some change.

Dr. Bogart:

I move it continue in alphabetical order, and I move that Dr. Pahnish of Arizona be the next Chairman.

Dr. Bennett:

I second the motion.

Motion carried.

Dr. Nelms:

That brings us to the matter of a meeting place for next year. The only place I have heard from is the U. S. Range Station at Miles City. Nat Kieffer extended an invitation to the group to meet there in 1964.

Dr. Cobb:

There has been considerable discussion regarding the possibility of having the meeting in Hawaii. We have not given you an invitation previously because of the structure of the regional set-up and it was discouraged at the regional directors' level. I don't know what has taken place in this regard but now that there has been a change in funding I would think there might be no reason why we should not meet in Hawaii. We have things in Hawaii we could show you, including beef cattle. I think you could do us a lot of good. We need some help with our cattlemen. If you should come over we could use some of you to speak to our cattlemen. As project leader and as Department Head I would certainly like to see you come.

Dr. Bailey:

I feel the same as Miles City. We would certainly like to have the group in Nevada in 1964 or 1965. We have a theme for the meeting worked out. We would like you as soon as you can come, but as I understand it, in 1964 the Society meeting would be in Montana.

Dr. Cobb:

There is some confusion as to time. If you meet in Hawaii I would suggest you meet in the winter. Next summer it would not be possible, for I will not be there. But I shall extend the invitation any time after September of 1964.

Dr. Bogart:

If we were going to Hawaii probably what we would want to do would be not have a meeting in the summer and then maybe go in December or January. If on the other hand we are not going to Hawaii we would need an invitation to Miles City or Nevada. I think it would put people on the road a long time if they went to Montana, then to Nevada, then back to their respective stations. If we meet at Nevada in 1964, it should be at a later time than immediately after the Western Section meetings.

Dr. Nelms:

There is one other idea to be considered. We have never been on the Reno campus or Hawaii. We have been in Miles City.

Dr. Cobb:

I don't want to pressure anyone, but I do want to put some figures before you. You can leave San Francisco at 4:00 p.m. and arrive in Honolulu at 6:00 p.m. So no one would need to feel that time spent and per diem would be excessive. The fare is \$266 round trip from Los Angeles or San Francisco, \$232 from Portland. From Portland, San Francisco, or Los Angeles you can fly Pan American or United, from Seattle by Pan American or Northwest.

Pan American has a winter fare effective November through May of \$200 round trip from Los Angeles or San Francisco.

The island of Hawaii is where our work is going on, and that is where our major ranching is. The cost is less than \$40 round trip to Hilo.

The other factors on cost--if you have a reasonable per diem I don't think there is any problem in staying within your level.

Those are the factors as I see them. You are very welcome to come to Hawaii.

Mr. Swanson:

Due to the fact that Dr. Stonaker is away I am speaking for him but I think he would be in favor of this and Dr. Wheeler has indicated he is in favor of it. I would make a motion that this group meet in Hawaii in the winter of 1964-65.

Dr. Bogart:

I second the motion.

Dr. Cobb:

I might mention that we have had the honor and pleasure of entertaining the Committee of Nine in Hawaii. Possibly the W-1 Committee should follow the Directors.

Dr. Bennett:

As I see it, it will be up to each to work through his Director for authorization.

Dr. Nelms called for a vote. Motion carried.

Mr. Willson:

Suppose members cannot get the approval to go.

Dr. Clark:

If more than half get the approval, the meeting will be held there, I suppose.

Dr. Bogart:

I think what the committee members should do is to let their directors know about this before too long and if they say they will not clear them the members should clear this with the Chairman of the committee.

I think there is a lot in what Estel said, that the Hawaii project would profit by a visit from W-1.

Dr. Cobb:

I would suggest that this be left open and left in the hands of the executive committee in conjunction with the project leader of the Hawaii station.

Dr. Bogart:

I so move.

Dr. Bennett:

Second.

Motion carried.

Mr. Swanson:

I think you should discuss the possibility of an informal meeting at the Western Section meeting in Bozeman next summer.

Dr. Bogart:

I think if the Chairman felt there were matters that should come up he should let the Committee know about them and we could get together at some time during the meeting.

Dr. Bogart:

I would like to make a motion that we give our hearty thanks to Dr. Bennett and to Utah State University for their provision of very fine facilities, their entertainment, and looking after us so well.

Dr. O'Mary:

Second.

Dr. Nelms:

That is very appropriate, Dr. Bogart. A vote.

Motion carried.

Dr. Nelms:

The Committee would appreciate any comments from Dr. Warwick.

Dr. Warwick:

Usually I don't have any special matters for these occasions, but this time I have a few thoughts to present--a general statement of policy of Animal Husbandry Research Division.

ARS-AHRD is interested in regional research and we certainly feel it is the procedure of the present where problems of beef cattle are concerned. We plan to continue very much along former lines, particularly regarding coordination of beef cattle studies. I have prepared a statement of policy which I will not take time to go over in detail now, but will ask that it be put in the minutes in full and I urge each of you to read this.

Our Division has been cooperating actively in three regional beef cattle breeding projects for periods of from 15 to 18 years, and the time may be opportune for restating the Division position and indicating changes which may be anticipated. The procedures, of course, conform to general policies of the U. S. Department of Agriculture's Agricultural Research Service in these matters.

First, it is a definite policy of the Agricultural Research Service of the United States Department of Agriculture to cooperate with State Experiment Stations in the conduct of regional projects. This position has been clearly set forth in Administrative Memorandum No. 110.3 dated 4/19/63 representing a revision of an earlier one from the Administrator's Office which read in part as follows:

"It is Departmental policy to encourage wholehearted cooperation by its research divisions in regional research projects whenever, by reason of their experience, personnel and facilities, such divisions are in a position to contribute to the planning and/or the prosecution of such regional projects. Divisions equipped to make significant contributions to regional projects will normally be invited to name representatives on the technical committee that guide the conduct of such projects. Such representatives shall prepare plans to coordinate pertinent work of their respective divisions with the regional projects as a whole and explore opportunities for effective cooperation in the overall effort.

"Department research divisions are authorized to:

Commit themselves to participation in regional research projects whenever they are in a position to make a significant contribution to such projects. Contributions may take various forms including the supplying of useful data, providing assistance for coordination, furnishing technical advice and counsel or assuming complete responsibility for a distinct phase of the regional effort."

Second, it is the unequivocal belief of personnel of the Beef Cattle Research Branch and the Animal Husbandry Research Division that problems of the kinds typified by beef cattle breeding are especially suited to the regional approach. It is our belief that the considerable body of knowledge regarding beef cattle breeding now available would in all likelihood not be available had the regional approach not been inaugurated in the 1940's.

Coming now to more specific aspects, I would like to discuss our participation in these projects and indicate some possible future trends in this participation.

At the inception of the three regional beef cattle projects, it was jointly decided that a major contribution of our Division would be that of providing a Coordinator for each project. Although I was not a party to these original discussions, I believe the basic ideas were that the Coordinators would function in a number of ways including (1) taking care of various administrative aspects of the project including preparation of annual reports; making arrangements for annual meetings; circulating copies of projects for approval, etc.; (2) serving as an arm of the Administrative Advisor in maintaining liaison with the regional association of Directors and with the U. S. Department of Agriculture; (3) presenting facts and results of the project to the public and in other ways maintaining contact and liaison with industry; (4) counseling with State project leaders and Federal field station personnel regarding the technical aspects of projects being developed and in operation; (5) counseling with State and Federal personnel regarding the analysis and publication of data from contributing projects; and (6) summarizing data and preparing publications on a region-wide basis where such combination and summarization appeared most desirable for arriving at answers desired.

The Division also included the beef cattle breeding research done at its six field stations (each operated cooperatively with the state in which located) as parts of the regional breeding projects.

In addition, the Division made certain moneys available under either cooperative agreements or memoranda of understanding to initiate and support cooperative research at many of the State Stations having contributing projects in regional projects. At the time the regional projects were initiated, it was believed that Congress would add increments to Research and Marketing Act funds and that both the Department and the States could look forward to substantial additional funds. As I understand it, what was envisaged at that time was a true partnership in which the Division would use its funds to substantially support particular research projects in the States to augment the funds the States themselves were putting into the work.

Thus, the thinking was that as more funds for this work became available to the Division that additional support would be added to on-going projects, as the progress of the projects justified.

So much for the original plans in regard to Divisional cooperation in the three regional projects. I believe it is fitting that we take a look at what has been done in these regards and what the future looks like insofar as we can see it at this time.

The three Coordinator positions were established and have, I believe, over the years functioned essentially as originally envisioned. In general, they have apparently functioned to the satisfaction of most persons concerned. When vacancies have occurred from time to time, the question has been reopened as to whether the position should be refilled or whether the available funds might be more effectively used in other ways. Agreement has not been unanimous on this, but in each case the overwhelming sentiment among both State and Federal people involved has been that the Coordinator positions are worthwhile and represent a useful expenditure of money. Thus, they have been continued up to the present time. Some changes in function have occurred and others seem to be desirable in the future. First, the Coordinators have been given increased responsibilities for direct participation in and for leadership of the Beef Cattle Breeding projects at the federally owned stations. Second, it has for some time been our feeling that with the development stages of the original projects largely completed, Coordinators would need to spend less time in travel and promotional activities of various kinds with the result that more time should be available for personal research and for research involving the summarization of data from two or more stations in the region when this approach is agreed upon by the technical committee. It is our thinking that Coordinators can be most useful and effective if this trend continues. With this thought in mind we have within the past year changed their titles from "Coordinator" to "Investigation Leader" since we believe this term more adequately describes their present functions. I want to emphasize that these are merely the official U. S. Department of Agriculture titles and that State personnel are at perfect liberty to continue considering them as Coordinators.

Beef Cattle Research projects at the federally owned field stations have continued to be parts of regional projects as originally planned, and I see no reason to anticipate that this will not continue to be the case in the future.

The third aspect of cooperation, namely the assignment of Federal funds to cooperating State Experiment Stations for carrying on cooperative research, has been the least satisfactory of the three avenues of cooperation originally planned. The anticipated increments to the Research and Marketing Act funds were not appropriated with the result that funds available for cooperative research have from the very beginning been extremely limited. During the same period costs of doing research have increased and it has been necessary in a few cases for the Department to reduce its support to cooperating states in order to maintain other aspects of the cooperative program. The net result is that we are putting relatively small sums of money into cooperative research at a fairly large number of State Experiment

Stations. I trust that even these relatively small amounts have been useful to the stations involved, but I believe you will all agree that the allocation of sums of from \$1,800 to \$6,000 into a State project usually represents a relatively small part of the total input and is far from being a true partnership type of situation.

Situations of this kind, not only in the Animal Husbandry Research Division but in others within the Agricultural Research Service as well, have been critically examined in recent years, and it is the general policy that Federal funds can be more effectively used if they are consolidated at fewer locations where the Federal contribution would be substantial and where a true partnership situation would be feasible. Limited though these funds are, we still want to keep them in the various regions and to make the most effective use of them possible. There is the very real possibility that within each region they may in the future be concentrated at some one, or certainly not more than two or three locations where work can be done of a kind which definitely serves the entire region. It would appear that such things as test stations where lines of cattle developed at several stations and the breeding systems used in their development could be evaluated under standard conditions would be one such valid use for these funds. Development of such things as blood typing labs to serve the region, frozen semen repositories, development and maintenance of control herds, etc., are other things that would fit in this general category.

It is not our intention to make immediate drastic changes in these regards but on the other hand, all of you should recognize that over the next several years we are likely to be moving in the direction of consolidation of these funds at a limited number of locations. We trust this can be done without disruption of present contributions of States to regional projects and that the end result will be a more effective contribution on our part. It should also be realized that if additional Federal appropriations for Beef Cattle Research are not forthcoming to cover continually increasing costs of carrying on other activities including the maintenance of a Coordinator in each region and the support of federally-owned stations, it may be necessary to transfer all or part of the funds now going to States for cooperative work to these activities in order to maintain them. I hope this will not be necessary, but we might as well be realistic and realize that it may be. As matters now stand, we have to say that these two activities have higher priorities than the allocation of funds to States for cooperative work in view of the distinctly unequal financial partnership situation we presently have in most of these situations.

In conclusion I would like to reiterate that we in the Department feel the regional approach has been effective in Beef Cattle Breeding Research, is likely to be even more so in the future, and that the joint participation of our organizations and the State Experiment Stations represents a desirable arrangement which should continue on a partnership basis. In view of the long-time nature of much of our work, it is certain that research in beef cattle breeding will need to continue for many years if we are to effectively serve the industry.

Dr. Burris:

You all have copies of some notes I prepared. I think it is enough now just to call attention to 1 A.--New and revised regional projects.

1. Changes in procedure for Regional Research effective July 1, 1963:
 - A. New and revised regional projects will not use contributing project outlines, but each station's responsibilities will be included in the regional project outline.
 - B. Regional research funds will be distributed to Stations and allocated by the individual Station Director to contributing projects of regional projects as he sees fit (much like the Southern Systems). Projects can contribute to regional research in another region at the Director's discretion and with acceptance of the respective technical committee.
2. The Agricultural Science Review, a journal, has been established by CSESS for the publication of technical review articles in various areas of agriculture. Contributing manuscripts are currently being accepted.
3. A new system of CSESS review of station research has been initiated this year. It will mean that research will not be reviewed each year, but at intervals up to four years. The reviewer will be closely associated with any research area which he reviews. Increased time will be available for review of the research program.
4. Hatch projects using the Form 20 have been placed on file in the Science Information Exchange, Suite 311, Universal Building, 1825 Connecticut Avenue, N.W., Washington 9, D. C., along with other unrestricted research projects having government support. Information on specific topics is available from this agency.
5. In July 1963, House of Representatives Bill 40 to authorize Federal grants to State Agricultural Experiment Stations on a matching fund basis to provide additional facilities for research was passed. There is no current budget under this Act. The Act provides for distribution of funds on a formula basis.
6. A book titled, "State Agricultural Experiment Stations, A History of Research Policy and Procedure," was published in May 1962.
7. Current Bills pertaining to the humane treatment of experimental animals include Senate S 533, S 1041 and House of Representatives HR 4620, HR 4840, HR 4843, HR 4856 and HR 5430. Hearings were held on September 28 and 29, 1962, on HR Bills introduced in the 87th Congress and are available from the Committee on Interstate and Foreign Commerce, H.R.

8. PHS Publication No. 1024, Guide for Laboratory Animal Facilities and Care, prepared by the Animal Facilities Standards Committee of the Animal Care Panel and adopted by the Institute of Laboratory Animal Resources, National Academy of Sciences, National Research Council, is available from Public Health Service, HEW.
9. USDA Advisory Committee for Dairy, Livestock, Sheep and Wool and Poultry met at Ames, Iowa, on February 18-21 at the National Animal Disease Laboratory. The report of the Animal Husbandry Research Division on current program and research progress prepared for these committees has been sent to station directors, as has the report and recommendations of these committees.
10. Requests for technical information may be directed to the National Referral Center for Science and Technology, Library of Congress, Washington 25, D. C. This agency will refer inquirers to organizations, institutions or individuals who are in a position to furnish information desired.

Dr. Clark:

In regard to your second point about Agricultural Science Review, would you care to comment on that. You state articles are now being accepted. From whom, and through which journal?

Dr. Burris:

We have an editor. He has directed a letter to all station directors, I believe to the various heads of agencies in ARS, and actually any review article in any of its phases would likely be acceptable if it was of sufficient interest and of restricted length. I think a few short ones and a few long ones may be used. Long ones would not exceed 10 to 14 pages. If there are people interested in writing such a review article or who are interested in getting information they could get it by writing to the editor or to Dr. Byerly, or to me for that matter. If you wrote to me, I would forward your inquiry.

I think this should be published quarterly and they hope to get the first volume out this fall. They had a target date but it has changed. Possibly November or December.

Dr. Clark:

I have nothing in particular to bring up except that when we ask you for something we certainly would appreciate a reasonably prompt reply for it is helpful to us in servicing requests that come from the various offices or other requests that come from time to time. I would like to ask you to be as prompt as you can.

I should say, also, that during the past year a sizable amount of data analysis has been accomplished through our office--more than at any time I have known during the history of this project. That has helped in many areas in bringing blocks of data into useful form. Flower, Pahnish, and Harwin have been able to get major publications and analyses underway as a result of using the Denver facilities. Holland

we hope to activate in this same direction. Certain state institutions have acquired facilities and hope to do their own work but in some cases the situation changes to the point where possibly cooperation through our center can be quite useful in getting data analysis done quickly. Whatever we can do, you should all know we have no selfish interest except to help W-1 and we will keep our data in the best form possible so it can be put into manuscript form as soon as possible. Jim and I both are ready to help wherever we can. There are certain limitations we must operate under but we are going to do our best to make W-1 very fruitful.

Dr. Combs:

I don't think it is appropriate to invite this group to meet as a group in Alberta, but if the opportunity presents itself, and Montana is not too far away, I think we have some work you would be interested in seeing in Alberta. If you are traveling and vacationing we should be happy to welcome you to Edmonton.

Dr. Nelms:

Is there any other business, or are there other comments? If not, is there a motion to adjourn.

Dr. Bogart:

I move the meeting adjourn.

Dr. Holland:

Second.

ADJOURNED



